AN ABSTRACT OF THE THESIS OF

Vidya Rajaram for the degree of Master of Science in Computer Science presented on September 22, 2006.

Title: Getting to Local Information: The Role of Different Costs

Abstract approved:

____

Margaret M. Burnett

Finding information can cost a significant amount of time, even when the information is already stored on the user's local computer system. There is significant research aimed at reducing these time costs, but little research into exactly what these costs are or how they impact people's use of tools and technologies to access local information. This thesis presents a methodology for investigating such issues, and uses the methodology to report empirical results on ways people access local information and how these ways tie to different types of costs. Our results fill in gaps in what is known about the problem of accessing local information, thereby helping to inform technological solutions to the problem.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **22 SEP 2006**	2. REPORT TYPE	3. DATES COVERED **00-00-2006 to 00-00-2006**

4. TITLE AND SUBTITLE **Getting to Local Information: The Role of Different Costs**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Oregon State University,School of Electrical Engineering and Computer Science,1148 Kelley Engineering Center,Corvallis,OR,97331-5501**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Finding information can cost a significant amount of time, even when the information is already stored on the user?s local computer system. There is significant research aimed at reducing these time costs, but little research into exactly what these costs are or how they impact people?s use of tools and technologies to access local information. This thesis presents a methodology for investigating such issues, and uses the methodology to report empirical results on ways people access local information and how these ways tie to different types of costs. Our results fill in gaps in what is known about the problem of accessing local information, thereby helping to inform technological solutions to the problem.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**84**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Getting to Local Information: The Role of Different Costs

by
Vidya Rajaram

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented September 22, 2006
Commencement June 2007

Master of Science thesis of Vidya Rajaram presented on September 22, 2006

APPROVED:

Major Professor, representing Electrical and Computer Engineering

Director of the School of Electrical Engineering and Computer Science

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Vidya Rajaram, Author

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my advisor Dr. Margaret Burnett for her constant support and guidance during the last two years. I am grateful to her for teaching me and guiding me at every step and helping me advance towards my goals. She has given me a lot of responsibilities which has helped me learn and grow in my research field. I could not have imagined a better advisor and mentor during my tenure at OSU.

I would also like to thank Dr. Simone Stumpf who has been of great support to me in my research. I have learnt a lot from her during this period. I would like to thank Dr.Timothy Budd, Dr. Carlos Jensen and Dr. Eric Skyllingstad, for accepting to be on my committee.

This work has been co-performed and co-authored by Dr.Margaret Burnett, Dr.Simone Stumpf, Dr. Jonathan Herlocker, Anton Dragunov, Evelyn Wick, Juliana Lynn and Kevin Johnsrude. I would like to thank them for helping me in this research endeavor. I would also like to thank the members of my TaskTracer research group. Without their encouragement and support this study would not have been successful.

I would also like to thank the statistical consultants Uran Chu and Joy Toyama who have given me valuable statistical guidance to carry out my analysis. I would also like to thank the participants of my study. Last but not the least, I would like to thank my parents, sister, brother-in-law and friends for their constant encouragement and support throughout my graduate studies.

This work was supported in part by the EUSES Consortium via NSF grant ITR-0325273, by NSF grant IIS-0133994, and by DARPA grant HR0011-04-1-0005, contract NBCHD030010.

TABLE OF CONTENTS

Page

1. Introduction....1

2. Background....3

  2.1 TaskTracer....3

  2.2 User Costs....4

    2.2.1 Attention Investment Model....4

    2.2.2 Attentional User Interface....6

  2.3 Finding Files....7

3. Research Approach....9

4. A Cost-Centric Methodology For Investigating Resource Access....10

  4.1 The Model: Possible Alternatives....10

  4.2 Measuring Actual Costs....13

  4.3 Measuring Optimal Costs....13

  4.4 Measuring Perceived Costs....15

5. Experiment Design....16

  5.1 Participants....16

  5.2 Procedure....16

  5.3 Task....17

6. Results....20

  6.1 Alternatives, Choices, and Their Actual Costs....20

  6.2 Consideration of Optimal Costs....25

TABLE OF CONTENTS (Continued)

Page

6.3 Roles of Perceived Costs 26

7. Up-Front Costs..27

7.1 Up-front Cost of Choosing an Alternative...27

7.2 Up-front Costs in Learning New Alternatives..28

7.3 Behavior Modification Is Possible...29

8. Implications...32

8.1 Suggested Usage of The Measuring Devices By Researchers and Designers of Task-Centric Environments...32

8.2 Implications of the Results..34

9. Conclusion 36

Bibliography 38

Appendices...41

Appendix A: Tutorial...42

Appendix B: Tasks...50

Appendix C: Questionnaires...54

Appendix D: State Diagrams 62

Appendix E: 27 ways..70

Appendix F: Field Visits...71

LIST OF FIGURES

Figure	Page
1: Task Explorer	4
2: State Diagram	11
3: Folder Hierarchy	18
4a: Quiz Software – Text Input Question	18
4b: Quiz Software – Multiple Choice Question	18
5: Actual Cost	21
6: Number of Alternatives Used	22
7: Network Diagram	23
8: Popularity of Alternatives	30

LIST OF TABLES

Table Page

1: AIM Variables 5

2: GOMS 12

3: Alternatives Used.. 20

4: Alternatives Known and Used 22

LIST OF APPENDIX FIGURES

Figure Page

1a: Desktop Snapshot – Familiar Ways ... 58

1b: Application Snapshot – Familiar Ways ... 58

2a: Desktop Snapshot – Perceived Cost ... 59

2b: Application Snapshot – Perceived Cost ... 59

3a: Desktop Snapshot – Frequency of Use ... 60

3b: Application Snapshot – Frequency of Use ... 60

4: Choose an Alternative Path ... 62

5a: Desktop Chosen ... 62

5b: Existing Windows Explorer Chosen ... 63

5c: Address Bar Chosen ... 63

5d: Quick Launch Bar Chosen ... 64

5e: Links Toolbar Chosen ... 64

5f: Existing Application Window Chosen ... 65

5g: Start Menu Chosen ... 65

5h: Open Application from “All Programs” ... 66

5i: Open File from “RUN” ... 66

6a: Open File from “My Recent Documents” ... 67

6b: Open File from “My Documents” ... 67

6c: Open File from Windows Explorer ... 68

6d: Open File from Application ... 68

6e: Open File Using Search ... 69

LIST OF APPENDIX TABLES

Table Page

1: 27 Ways of Getting to a File 70

2: Files Used Frequently 71

Getting to Local Information: The Roles of Different Costs

1. Introduction

Computer users who spend considerable time processing information (termed *knowledge workers* in this thesis) access much of this information on computer systems. Unfortunately, the task of accessing such resources, even when stored locally in files and folders on the user's computer, is often not a simple one. One reason may be that the information may not be organized according to their current needs — or not even be very well organized by any criterion. Several research efforts have helped to shed light on user processes for organizing and retrieving information [Bannon et al 1983, Malone 1983, Boardman and Sasse 2004], and the difficulties they run into along the way [Barreau et al 1995, Bruce et al. 2004, Jones et al. 2005, Kaptelinin 2003, Ravasio et al. 2004].

The good news is that the knowledge worker has a number of choices about how to access a resource on her computer, and at least one of them is likely to be very efficient. Unfortunately, this is also the bad news. For example, she might get to it through the "Recent Documents" list, or by navigating from an open Windows Explorer window. Each choice incurs different costs and risks for her — navigating is straightforward but can be time-consuming, looking through the "Recent Document" list takes time and the resource might not be listed in it, and so on. Clearly, all of these choices carry different costs and risks of failure, and considering each in order to choose the best seems warranted, yet adds a cost of its own.

Recent improvements in desktop search do not eliminate the problem: users often still navigate around manually. For example, previous research has found that users prefer manual navigation to search in many cases, especially when it is difficult to produce appropriate search terms such as file names; that novices particularly prefer manual navigation over search; and that even skilled users use search only occasionally [Barreau et al 1995, Ravasio et al. 2004].

In response to the reported difficulties users have in accessing their resources, there have been several research efforts to help users better organize and retrieve information [Bellotti et al. 2003, Czerwinski et al. 2004, Dragunov et al. 2005, Kaptelinin 2003, Smith et al. 2003]. This has led to a proliferation of approaches to support access to resources. However, these works have not attempted to distinguish the types of costs of users' difficulties, illuminate how different types of costs impact users' behaviors, or pin down precisely which of the costs could be reduced by the proposed solutions.

We would like to shed some light on these issues, so that technologies aiming to reduce user costs have a clearer target at which to aim. We conceptually define *cost* to mean the user's time and effort spent on getting to local information. We consider three different types of cost: (1) *actual costs* borne by the users, (2) *optimal costs*, i.e., the minimum amount of time and effort required to access a resource under specific assumptions, and (3) *perceived costs*, i.e., the users' opinions of the costs of different ways to access resources. (Operational definitions of these terms will follow.) We use the Attention Investment Model [Blackwell 2002] as a basis to understand the cost-risk-benefit decisions made by users while accessing resources.

In this thesis, we first present a cost-centric methodology for investigating these costs. We then use this methodology and present empirical results of an experiment that specifically investigated the roles of the three different types of costs on users' choices. Our results demonstrate that careful consideration of the roles of these three different types of costs can reveal useful insights that help inform technologies in the domain of interfaces for local resource access.

2. Background

2.1 TaskTracer

TaskTracer is a desktop software system that tracks in detail how knowledge workers work on tasks and uses this information intelligently to increase their productivity and efficiency. The main goals of TaskTracer are to make user interfaces task-aware, help with interruption recovery and improve personal information management.

The central concept of TaskTracer is that knowledge workers organize their work into discreet work units called tasks. This system supports Task Management by grouping information automatically into tasks. Knowledge workers continually consume and produce information. This information is usually available in different locations and has to be accessed using different applications such as Microsoft Word, Microsoft Excel, Microsoft PowerPoint, Web browsers etc. TaskTracer helps to bring all the required information from different locations and different application types to one place by associating all this information with a task. Thus one of the main goals of TaskTracer is to help the users to easily access resources associated with a task.

The resources associated with a task are displayed in a list in the “TaskExplorer” which is the UI component of TaskTracer (See Figure 1). As we can see from the UI (Figure 1), all the tasks are displayed in the left pane. On selecting a particular task, all the resources associated with that task can be viewed under the “All” tab. To view resources of a particular application type, we can choose the corresponding tab.

Knowledge workers multi-task. As they are working on their tasks they are continuously trying to locate and open resources associated with that task. Such actions of locating and opening resources itself might lead to an overhead cost. In

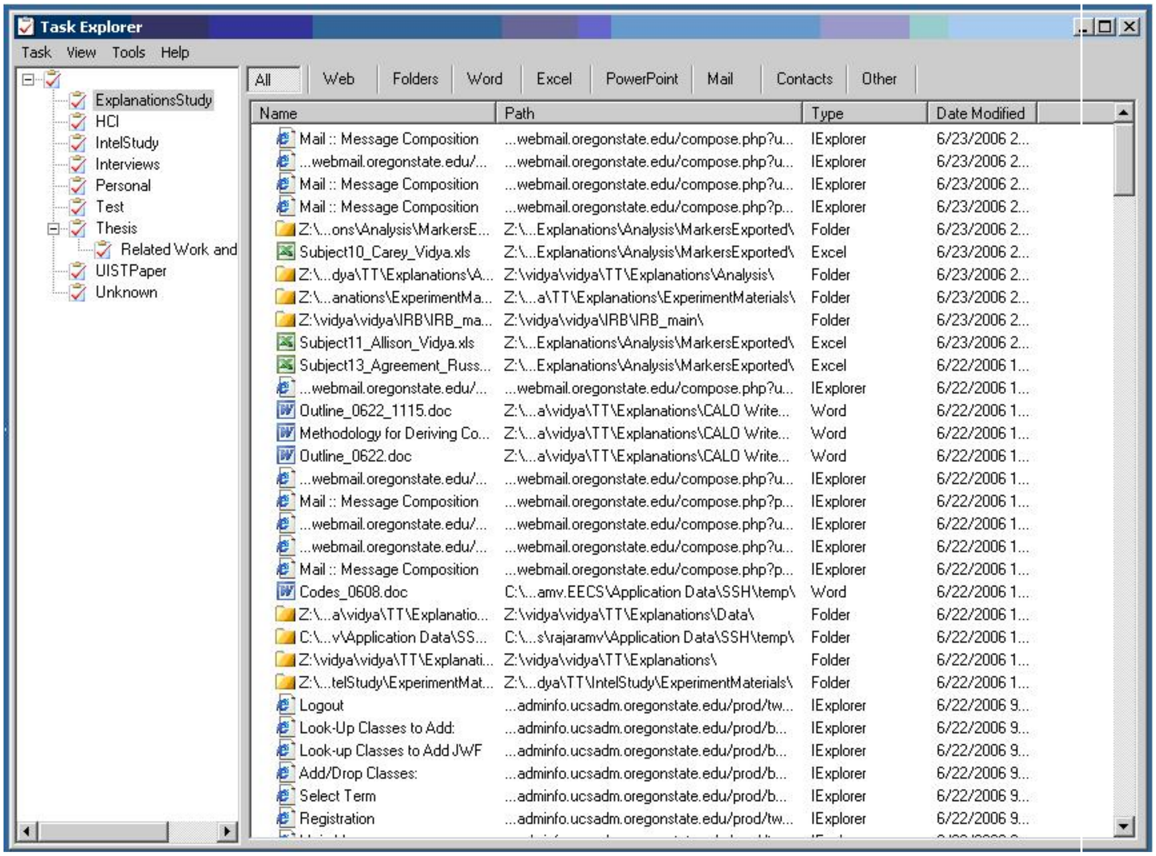


Figure 1: TaskExplorer – The resources associated with the "Explanations-Study" task is displayed as a list

order to avoid such overhead costs and to help with personal information management, the TaskTracer UI has been designed to minimize the users' cognitive and physical costs of locating information. In order to inform the design of TaskTracer, this thesis is focused towards identifying the users' current strategies and nature of overhead costs associated with accessing resources in the traditional windows environment.

2.2 User Costs

2.2.1 Attention Investment Model

Our investigation makes use of the Attention Investment Model [Blackwell 2002] as a basis for understanding costs. Attention Investment Model is a cognitive model that analyzes people's decisions about how to perform tasks based on their perceptions of costs, benefits and risks. This predictive model describes how users decide to allocate their attention by conducting a cost-risk-benefit analysis during problem-solving, in which the units they are weighing up are the cost of their attention. In this model, risk is expressed as a probability of wasted attention or unanticipated additional attention. Cost and benefits are expressed in "attention units", a concept similar to time that also includes the notion of degree of on-task focus by the user. In these units, the expected benefit of an action is compared to the investment required and to the risks that the cost may be paid without receiving the expected benefits after all.

Variable	**Attention Investment Model**	**Examples from Our Work**
Cost	Perceived attention units to get the work done	Perceived cost of actually finding the file by going through that path
Investment	Perceived attention units expended towards a potential reward	• Perceived cost of choosing a path • Perceived cost of learning to use a particular path
Pay-off	Perceived reduction in future cost that will result from the way the user has chosen to spend attention	Perceived time savings of finding the file by going down the path chosen
Risk	Perceived probability that no pay-off will result or even that additional future costs will be incurred	Perceived probability of not finding the file by going down a particular path and of extra time being needed to backtrack and go down a new path.

Table 1: AIM Variables

The variables involved in the cost-benefit analysis of the Attention Investment Model and their application to our work are shown in Table 1.

The Attention Investment Model focuses on *perceived* costs, risks, and benefits. This aspect of the model is critical: often users make choices based on limited information. The users' perception of costs, risks, and benefits may be influenced by their past experiences, and may have little to do with the actual costs, risks, and benefits. The perceived amount of benefit includes not only the immediate benefit, but also the extent to which the user believes that their investment of time may reduce future costs.

The Attention Investment Model will serve as an intellectual framework in our investigation into how people make choices among ways to access resources. In particular, we are interested in understanding how peoples' decisions and the strategies they use in accessing resources relate to perceived cost, risks and benefits as pointed out by the Attention Investment model. Additionally we are interested in studying the relationship between their perceived costs, their actual costs and the optimal costs.

2.2.2 Attentional User Interface

Closely related to the Attention Investment Model is the Attentional User Interface (AUI) model [Horvitz et al. 2003]. The AUI model also draws from economic models of attention and investment. The AUI model takes into account the information content of a potential interruption by the computer (such as a potential notification of an important incoming email message) in the context of the user's preferences and his/her current and recent online activities as detected by sensors. Although the AUI model does not consider cognitive activities directly, the user's physical activities can be regarded as indirect clues about the user's attention. The AUI model's purpose is to predict whether and how the computer should interrupt the user. From the perspective of our research, this is a critical difference between the AUI model and the Attention Investment Model — the Attention Investment Model considers what the *user* will do under specific conditions, whereas the AUI model considers what the *computer* should do.

2.3 Finding Files

Our work builds on the findings of previous researchers who have investigated the preferences and habits of people attempting to access local information, and how well their habits align with the mechanisms available. For example, numerous studies have found that people rely heavily on the classification of information into folders to facilitate retrieval, preferring manual browsing over logical search [Barreau et al. 1995, Jones et al. 2005, Ravasio et al. 2004]. One reason for this may be that users prefer to navigate to a desired file in small steps using context as a guide [Teevan et al. 2004]. Furthermore, users employ a limited number of manual browsing techniques [Kaptelinin 1996].

Keeping files and folders maintained in logical hierarchies costs users time. To save this time, various approaches for personal information management that do not rely on hierarchically structured file systems have been proposed. For example, one organization scheme is the "pile" or "data mountain", a loosely structured information collection [Dourish et al. 1999, Robertson et al. 1998]. Another approach is to show information in a time-centric visualization [Freeman et al. 1996, Rekimoto et al. 1999].

Time-centric organizations have the advantage of allowing the worker to return to records of past work, but for multi-tasking workers, a single timeline is a jumble of multiple tasks. Because projects, activities, and to-do items play an important role to the knowledge worker [Bannon et al 1983, Gonzalez et al. 2004], various tools have been developed to support grouping information in task-centric workspaces [Dragunov et al. 2005, Kaptelinin 2003, Smith et al. 2003, Boardman et al. 2003, Henderson and Card 1986,Ringel 2003].

Further information on the specific costs that users incur could be used to help these efforts to minimize costs, and helping to fill this gap is the goal of this thesis.

3. Research Approach

To investigate how people access local resources and their reasons for choosing different ways of accessing them, we developed a methodology that combines analytical and empirical devices and that distinguishes actual, optimal, and perceived costs.

We used this methodology to conduct an experiment to answer the following research questions:

- Among how many different ways must users choose to access resources?
- What roles do actual, optimal, and perceived costs play in the choices that users make?

We used the Attention Investment Model as an intellectual framework for the investigation, considering how the results might be interpreted using this model and what implications ensue for information access technologies.

4. A Cost-Centric Methodology for Investigating Resource Access

The methodology we present here consists of a model for locating resources plus three devices that can measure actual, optimal and perceived costs. (We enumerate complete details of the model in Appendix D).

4.1 The Model: Possible Alternatives

The core of our methodology is a state-transition model that reflects all the states and transitions for accessing local resources for a standard Windows system. The state-transition model reflects possible paths a user can take through this state space to access a resource, from root (deciding what first step to use) to leaf (finally opening the desired file). Each transition represents a choice to the user at that stage as to how to proceed next.

In this thesis, we use an abbreviation convention, in which each grey node is a *supernode* — a collapsed version of several states and transitions. Transitions marked *Decide* denote mental operations, those marked *Select* denote physical user actions such as mouse clicks and keypresses, and those marked *Navigate* are a shorthand notation indicating that both a mental operation to decide how to proceed and the sequence of physical user actions to reach the next state are included.

The model explicitly depicts the work required for the user to access a local resource, which can sometimes be quite a lot. For example, consider the path of opening a resource using My Recent Documents from the Start menu (Figure 2). Thus, in this example, first the user decides how to proceed from the top level, transitioning to the Start Menu Chosen state. The user then takes the actions to activate the Start Menu (Select transition). The user then navigates to the My Recent Documents supernode. There are then three more transitions within this supernode required to open the resource. At any time, the user could, of course, decide to try a

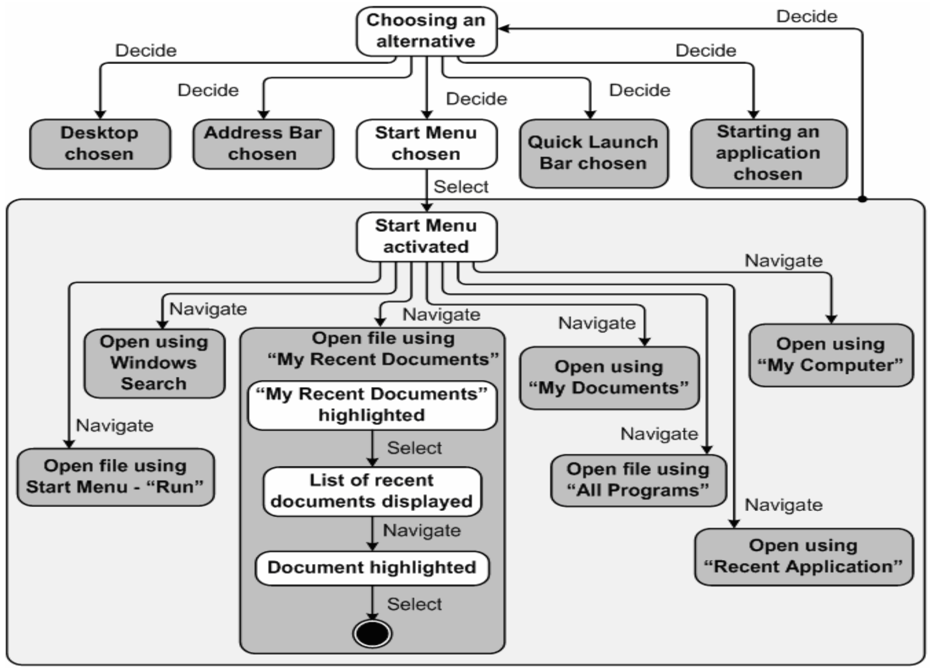


Figure 2: State Diagram. States and transitions involved in opening a file using the Start Menu's My Recent Documents.

Supernode (grey node):- A collapsed version of several states and transitions
Decide: - Mental operations
Select: - Physical user actions
Navigate: - Includes mental operations to decide how to proceed and the sequence of physical user actions to reach the next state.

different approach. This is depicted in the figure by the Decide transition leading out of the largest supernode up to the top level.

We chose to combine access paths with only trivial differences into groups, in order to make analysis tractable and useful. Such groups of access paths will be referred to as *alternative paths* in this paper. Each alternative path is named in the form of Leaf Node (Root Node). For example, if a resource was opened from My Recent Documents, which was in turn reached from the Start Menu as per Figure 2, this alternative path would be named My Recent Documents (Start Menu).

This model can be used as a "stand-alone" analytical tool for cost-based investigation into resource access. For example, this model can be combined with a GOMS-based [Card et al. 1980] approach to provide estimates of likely completion times for each alternative path by summing up the transitions (operators, in GOMS terminology [See Table 2]). The transition counts can be used as order statistics of all the existing alternative paths. Given such a model, new alternative paths can be added to the state-transition model, allowing user costs of the new alternatives to be estimated.

Operator	**Time required to perform this operation (seconds)**
K (Keystroke)	0.28
P (Point with mouse to something on the display	1.1
B (Press or release mouse button)	0.1
BB (Click a mouse button)	0.2
H (Home hands either to the keyboard or mouse)	0.4
M (Mental, thinking)	1.35

Table 2: GOMS – taken from [Card et al. 1980]

Consider three useful subsets of alternative paths. All possible in the Windows environment are termed *possible alternative paths*. Not all possible alternative paths are available to the user in a particular context (e.g., a resource may not be in the My Recent Documents list); this subset of possible alternative paths is termed *available alternative paths*. The choices actually made by users are their *chosen alternative paths*.

The model answers questions about only one of these subsets in a way that generalizes to all users: possible alternative paths. In order to also investigate actual and optimal costs for a given situation requires inclusion of the other two subsets.

Thus an instantiation of the model is needed, taking into account available alternative paths and chosen alternative paths based on a user’s concrete context and actions. This information can be obtained from the following three measuring devices.

4.2 Measuring Actual Costs

The first device measures alternative paths chosen by users, along with *actual costs*, which we operationally define here as time spent to open a resource. TaskTracer [Dragunov et al. 2005] was used to record each participant’s actions in our experiment, but similar systems can achieve the same result. The key is to record each action and the time needed to complete those actions, generating an electronic transcript of each participant’s session. TaskTracer listened in on all user interaction events such as keypresses, mouse clicks, and window focus changes. File open and close events were also recorded. In our instantiation of the device, actual costs for individual resource accesses were measured in seconds elapsed from the time of the first interaction event to look for a resource in the electronic transcript (state in the model) to the time of the file open event.

This device allows the investigation of "in usage" cost by providing a way to track and compare users’ traversal through the state space. The resulting data can be used, for example, to check the consistency of an estimated alternative path’s cost to actual usage, or to establish where users may need indicators that will help them make better choices.

4.3 Measuring Optimal Costs

The second measuring device addresses the set of available alternative paths to access resources that a participant did *not* use in each situation. This allows calculation of a form of *optimal costs* — the costs of the least expensive alternative path a user could choose to access a particular resource given the current state and context the user is actually in.

Context was gathered by recording *information snapshots* at each new situation. In our experiment, this occurred each time the user started looking for a resource and each time the participant opened a resource. The snapshot included extensive system state information, such as the current folder in the File Open Dialog box and files present in My Recent Documents, My Documents, the Recent Lists of each tracked application, and so on. The information snapshots were stored with the electronic transcript of user behavior for concurrent analysis.

Given available paths in context, optimal cost was computed by using the model to identify the transitions required to reach the required resource. The calculations used established times for operations involving mental operations, keypresses, and mouse clicks ([Card et al. 1980], See Table 2). For example, the time taken to open a file using Start Menu's MyRecentDocuments as shown in Figure 2 was calculated using the GOMS operators and timings as follows:

Optimal Cost for opening a file from MyRecentDocuments: M (Decide the path to take) + BB (Click the Start button) + M (Locate RecentDocuments in the submenu) + P (Point with mouse on RecentDocuments) + M(look for the file in the submenu) + P(Point with mouse on file) + BB (Click on the required file) = 1.2 + 0.2 + 1.2 + 1.1 + 1.2 + 1.1 + 0.2 = 6.2 seconds.

The alternative path with the lowest cost was used as the optimal cost. We cross-checked the achievability of these times for alternative paths, both by comparison to participant times when they actually used them, and by asking experienced computer users otherwise not involved in the experiment to open resources using these paths. In all the cross-checks, the fastest humans differed from optimal path cost calculations by no more than 20%. When there were differences, the humans were faster. Thus, when there are errors in our optimal cost estimates, it is when the estimates are too conservative (slow). No estimate can ever be perfect, and being overly conservative supports the safety of our inferences better than being too liberal.

4.4 Measuring Perceived Costs

The third measuring device is aimed at capturing users' perceptions of two factors of cost, and is done via a questionnaire. The first was participants' self-reported cost assessment of the alternative paths from their past experience with them, which is our operational definition of *perceived costs.* Specifically, the questionnaire included a 5-Likert-scale question about what their perceived cost to use each alternative path was (very easy to very hard).

In addition to perceived cost of ongoing usage, costs to learn to use alternative paths may arise. To ascertain whether learning costs might play a role in a user's overall perception of cost, the questionnaire collected whether the user was aware of each alternative path at all, or if the user knew of the alternative path beforehand but had only infrequently used it. These costs are collected by asking participants whether they were aware that an alternative path existed and their previous usage frequency (never to always). These questionnaires are available in Appendix C.

5. EXPERIMENT DESIGN

Observational studies in a controlled environment facilitate the search for causality and relationships for situations in which complete control is otherwise not possible. We conducted our experiment to investigate relationships between users' choices of alternative paths and how those choices related to the cost types.

5.1 Participants

Participants were recruited by email to student mailing lists. The participants were required to have some prior computer experience, but computer science majors and students with upper-division coursework in computer science were excluded from participation. Overall, 39 people (22 women and 17 men) took part in the study, with a mean 3.28 grade-point average and a mean 9.09 years of computer experience. All participants experienced the same treatment.

5.2 Procedure

Initially participants filled out a pre-session background questionnaire (available in Appendix C). Each participant was given a common set of resources (Word documents and Excel spreadsheets) in a pre-ordained folder hierarchy. After filling out the background questionnaire, they were then led through an introductory session (available in Appendix A), in which they were instructed to browse through and move the files provided to them so as to gain some familiarity with their location and contents. By opening the files and looking at their contents, participants also populated "My Recent Documents" in the Start Menu, and the "Recent List" in Word and Excel, ensuring that these ways of opening files would be available to them during the task.

In a 15-minute session, participants then worked with a practice task, which served the dual purpose of getting participants acquainted with the experimental set-up and of giving them a purposeful method of further familiarizing themselves with the content and location of the resources. Participants then had 45 minutes to perform the main experiment tasks.

Participants then filled out a post-session questionnaire (available in Appendix C), in which they were asked how they usually accessed resources in the Windows environment. These questions were asked post-session rather than pre-session in order to prevent the questions from influencing their behavior during the experiment. Although this design choice allows for the possibility of post-rationalization by participants, we considered this to be the less prejudicial choice. In order to obtain information about emotional costs (amount of mental and physical demand, frustration level, etc.), we used a modified version of the TLX survey [Hart & Staveland, 1988].

5.3 Task

The participants' task was to answer up to 40 questions (available in Appendix B) about the U.S. National Aeronautics and Space Administration (NASA). A question's role was to represent a single activity for a knowledge worker; hence, questions were designed to require thought, information search, and information communication.

Each question required information from one or more of the resources (Word and Excel files stored on the participant's computer). Participants were instructed not to use web search to obtain the answers. In order to maximize the need for these resources, well-known facts about NASA were avoided.

To control for confounding effects and to allow statistical comparisons between participants in terms of costs, each participant was given a common set of resources. The resources were structured into three folder levels, with seven top-level folders, a portion of which is shown in Figure 3. The leaves of the tree contained 50 Word

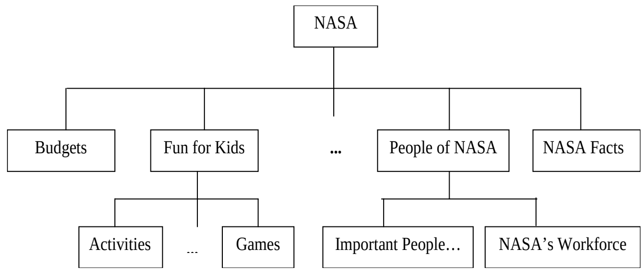
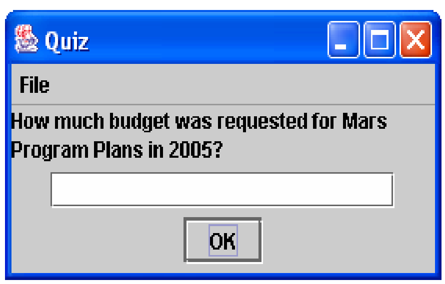


Figure 3: Folder hierarchy: The folder hierarchy used in the experiment.

documents and 5 Excel spreadsheets. The structure and names of these resources were devised by a non-technical end user, who we recruited for this purpose.

Questions were presented sequentially by software designed for the experiment (Figure 4a and Figure 4b). This *quiz software* presented questions with an input box for typing in the text answers or a set of radio buttons for answering multiple choice



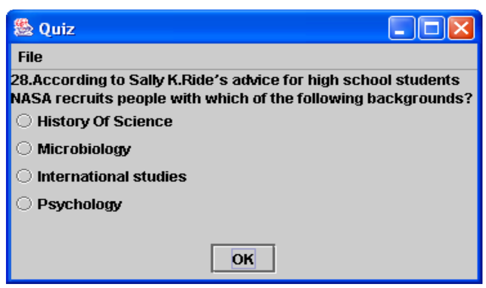


Figure 4a: Quiz software - Text input question. 4b: Multiple Choice question.

questions and prevented participants from skipping questions. The starting question for each participant was chosen at random.

We designed the questions so that three resources provided answers or partial answers to approximately half the questions in the experiment. This design choice was based on a set of field visits with 10 knowledge workers (office workers and educators, not software developers). The field visits revealed that all these workers had a small set of resources, usually two or three, to which they refer repeatedly and frequently. (The details about the field visits are available in Appendix F).

Knowledge workers deal with multiple tasks and interruptions. To model this aspect of the real world in our experiment, certain questions (randomly selected prior to the experiment) were interrupted after the participant had opened a predetermined number of resource documents. All participants were interrupted on the same set of randomly selected questions. When interrupted, the participant was forced to switch to another question (activity). The number of resources triggering a particular question's interruption was also randomly selected prior to the experiment. The participants did not know which questions would be interrupted. Time permitting, the interrupted questions were reintroduced later in the experiment to model the interruption recovery aspect of real-world tasks as well.

Once a participant had submitted an answer to a question, Windows Explorer (the graphical file browser) and any open resource documents (Word, Excel etc.) were closed automatically, so that participants would have to explicitly choose them again if they were needed later. The Word and Excel applications themselves, however, were left running, to allow the possibility of using the Recent List in the File menu of the applications or the File Open Dialog box if desired by the participant. The automatic closing of applications and documents was done to ensure that the starting state of each question was the same. The data was collected using the TaskTracer software [Dragunov et al. 2005] and this is discussed in detail in Chapter 4 - Section 4.2

6. RESULTS

6.1 Alternatives, Choices, and Their Actual Costs

Our state-transition model revealed 27 possible alternative paths. Clearly, the cost of making the decision from among so many different alternative paths would be high, even if all of these alternative paths were known to the user.

This suggests that there could be some alternative paths that a user never chooses. To understand to what extent this occurred, we counted the alternative paths that participants actually used during the experiment. As Table 3 shows, a mere 11 of the 27 possible alternative paths were used by any of the 39 participants. No participant used any path not represented by our current state-transition model.

Alternatives	Code	Participants	% of Participants
Windows Explorer (existing window)	WE	35	89.74
Windows Explorer (Address Bar)	AB	16	41.02
Windows Explorer (My Computer on Desktop)	MC	15	38.46
File Open Dialog (application)	FO	8	20.51
Recent List (application)	RL	7	17.94
Windows Search (Windows Explorer)	WX	7	17.94
Windows Explorer (Start Menu)	WM	6	15.38
Windows Explorer (folder shortcut on Desktop)	WD	3	7.69
Windows Explorer (Start Menu - RUN)	WR	2	5.12
Windows Search (Start Menu)	WS	2	5.12
My Recent Documents (Start Menu)	RD	1	2.56

Table 3: Alternatives Used

Table 3, in top row also shows how participants overwhelmingly chose to access resources through alternative paths involving Windows Explorer. (These results also mirror the proportion of individual resource accesses for which these alternative paths were used.) Once they had used Windows Explorer and there was an existing window for it, they kept returning to it (even though it may have been hidden).

We then looked at the actual costs of the alternative paths chosen by the users. The box plots in Figure 5 show the actual costs for each alternative path, calculated as per the measuring device described in Chapter 4-Section 4.2. As can be seen from the rightmost two box plots, searching was more costly than other alternatives. ANOVA analysis of all actual costs confirmed this, revealing a significant main effect on actual cost of search versus non-search (p<0.0001). Not surprisingly given the participants' abilities to choose their alternative paths, there were also significant differences among participants (p<0.0001) and there was a significant interaction effect (p<0.0001).

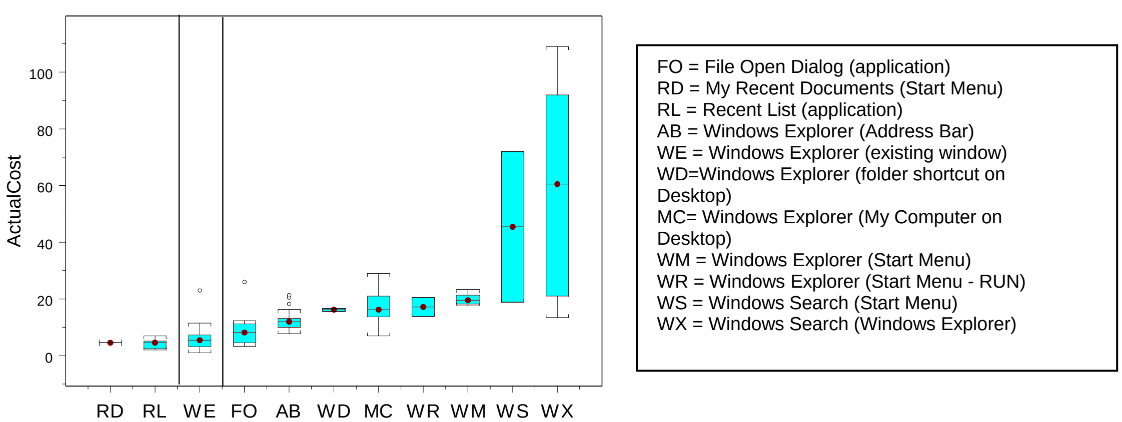


Figure 5: Actual cost of each alternative; see Table 1 for a legend. RD and RL are "recent lists", low in cost but viable only when they contained the desired file. WE existed only after a question's first file open. The other alternatives were always available.

We were interested in determining how many of the alternatives they used during the experiment and how many of those they knew from before the experiment. Most participants used 2 to 3 alternative paths (Figure 6) during the experiment. The mean number of chosen alternative paths per participant was 2.64. In the post-session questionnaire (available in Appendix C) we obtained information about the alternatives that they knew. We then compared this against the alternatives that they actually used. The results are shown in Table 4. Although the table does not yield significant results (chi-square test, p-value=0.1353), it is interesting to note that 90% of what they used, they already knew. Another interesting fact is that they used only 20% of what they knew.

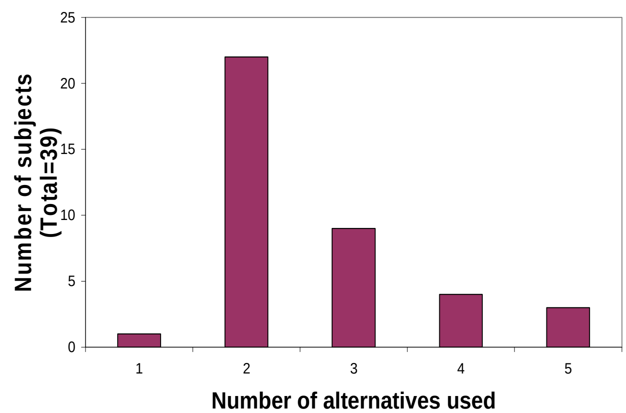


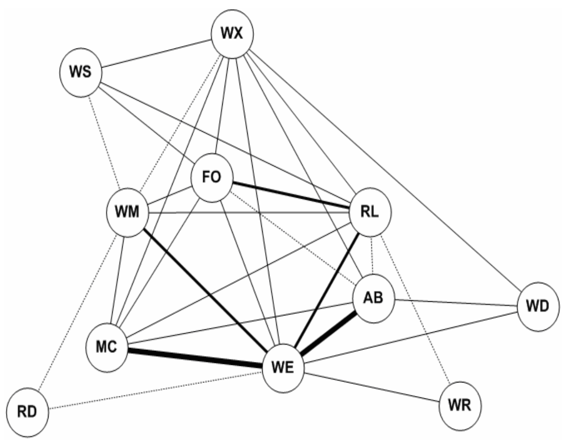
Figure 6: Number of alternatives used by participants.

Recall that the experiment included interruptions because of their presence in the real world. The results reported above and throughout this paper include both interrupted and non-interrupted situations. The trends for interrupted data and non-interrupted data were the same, and thus we did not separate them for analysis.

	Used	Not Used
Knew	59	256
Didn’t Know	7	61

Table 4 - Alternatives Known and Used

The network diagram in Figure 7 shows whether and how often a particular alternative was used in conjunction with another alternative. Nodes in the network represent the 11 alternatives that were used by participants in the experiment. An edge between two nodes indicates that both these alternatives were used in the experiment session by the same participant. The thickness of the edge between two alternatives indicates the number of instances in which the two alternatives were used together.



FO = File Open Dialog (application)
RD = My Recent Documents (Start Menu)
RL = Recent List (application)
AB = Windows Explorer (Address Bar)
WE = Windows Explorer (existing window)
WD=Windows Explorer (folder shortcut on Desktop)
MC= Windows Explorer (My Computer on Desktop)
WM = Windows Explorer (Start Menu)
WR = Windows Explorer (Start Menu - RUN)
WS = Windows Search (Start Menu)
WX = Windows Search (Windows Explorer)

Figure 7: Network Diagram - Combinations of alternatives

This network diagram again emphasizes the importance Windows Explorer had to the participants as a core component for accessing resources. Moreover, it reveals an application-centric approach, in that participants tended to use File Open Dialog (FO) together with Recent List (RL) in that application. In fact, it appears that participants had certain “constellations” of preferred strategies. There were also “anti-constellations” — certain combinations of alternatives that were almost never used together. For example, My Recent Documents (RD) was never used in combination with any kind of Windows Search (WS and WX), nor with any desktop shortcuts (MC and WD), nor with File Open Dialog (FO).

Discussion

It appears that the Windows Explorer alternatives were attractive to participants. This is consistent with previous findings reporting that users preferred strategies with interactive feedback about their status towards locating a file [Fu and Gray 2004, Teevan et al. 2004]. Windows Explorer excels in this regard by continually keeping users apprised of the context, which may help to explain its apparent popularity.

Note that some alternative paths were available only at certain points. For example, locating a file through My Recent Documents would only be successful if this resource had been opened recently enough to feature in the list. Even though the actual cost for an alternative path may be low, this potential risk could play an important role. In the terms of the Attention Investment Model [Blackwell 2002], attempting such alternative paths involved a risk to the participant that they may not receive the benefit of locating the file using that alternative path. In this event, yet higher cost would be incurred by having to backtrack and choose another alternative path.

Searching was not very popular. It is possible that an alternative search tool might have been more popular than the standard ones that were present in our experiment. Still, this result is in agreement with previous research [Jones et al. 2005, Kaptelinin 1996, Teevan et al. 2004] indicating that users in fact prefer manual browsing to searching. Note also that the actual costs of the other alternatives were much lower (and less variable) than the two alternatives that involved searching, which likely informed users' perception of the downsides of searching.

The constellations represent collections of tools that, in sum, seemed to cover everything a participant was trying to do. Having achieved this complete coverage of all the situations that were arising, a user has less incentive to seek out new alternatives, If so, this in turn suggests that new ways that could be developed may never or rarely be used, if they do not fit well in an existing constellation or catalyze a new one.

6.2 Consideration of Optimal Costs

How close did participants get to achieving optimal costs (as calculated by our measuring device)? Optimal costs did appear to influence their choice of alternative paths: there was a significant relationship between actual and optimal user costs (linear regression, $p<0.01$, $F[4,72]=6.695$, $R^2=0.2711$). Participants achieved optimal costs about 38% of the time in their access paths.

Notice, however, that optimal costs explain only about 27% of actual costs. Much of the time, participants seemed to return repeatedly to the same alternative paths, even when there were better choices. For example, Recent List and My Recent Documents, when they were available, could get participants to the files in only a small number of mouse clicks but instead other, costlier alternative paths were often used.

Discussion

The results show that, although participants tried to a significant extent to make choices that were linked to efficiency, they did not succeed in making the best choice in a large number of cases. The reason for this could be that their perception of alternatives' costs was not accurate. The Attention Investment Model suggests that users make decisions based on perceived costs, risks, and benefits — which may not be very close to actual or optimal costs. We next investigate this possibility to determine if their choice of alternatives was based on their perceived costs.

6.3 Roles of Perceived Costs

We investigated the relationship between their perceived cost of alternatives and their choice of alternatives. We obtained the following information from the questionnaire.

- Perceived Cost - How much work do you think it is to find the right files in the following ways? [Likert scale of Very easy-Very Hard]

Logistic regression is based on probabilities expressed as odds, and we used it to assess whether perceived costs or previous usage were predictive of whether a participant selected an alternative. We found that perceived cost (as measured by the questionnaire) of the alternative was not predictive of the choice of an alternative.

7. Up-Front Costs

Our results suggest that participants were trying to make choices linked to efficiency. Even so, they did not make the most optimal choices and their perception of costs had no relationship to the choices they made.

The costs that we have looked at so far are the ongoing perceived costs. According to the Attention Investment model, it is important to differentiate between the ongoing costs to get the work done as opposed to up-front investments to enable users to use the ongoing method of choice. We now turn our attention to these up-front costs to understand its role in participants' choices.

The Attention Investment model discusses the investment decisions that the users need to make when alternative courses of action are available. These are decisions that the users have to take initially while choosing an alternative path. Making the right investment eventually leads to a payoff but in order to make this investment users need to spend mental and physical effort which adds to their upfront costs. Our findings show that participants were sensitive to these up-front costs. Specifically there are two types of up-front costs that we observed. They are the (1) up-front cost of choosing an alternative path and (2) up-front cost of learning an alternative path.

7.1 Up-front cost of choosing an alternative

The following pieces of evidence support the importance of the cost of choosing to participants. First, participants only used a small number of alternative paths during the experiment, suggesting that they did not consider all alternatives before making a selection. In fact, the Attention Investment Model suggests that users would be unlikely to take the time to mentally compare a large number of alternatives, since the costs spent in advance on mental calculations to locate an optimal alternative would outweigh the cost saving gained from eventually carrying out an optimal alternative path. Second, participants knew about 8 alternatives on an average but they used only about 2. Third, we can see from the Table 4 in Chapter 6 - Section 6.1 that they used only about 20% of the alternatives that they knew. This implies that those 20% of the alternatives covered “well enough” everything that they wanted to do. Recall also that the set of alternatives they used formed constellations as shown in Figure 7 in Chapter 6 – Section 6.1. These constellations apparently covered everything that they wanted to do. This suggests that, in general, it is often unlikely that users will consider new alternatives because not considering them reduces their up-front choosing costs.

7.2 Up-front costs in learning new alternatives

We investigated the relationship between previous frequency of usage of alternatives and the users’ choice of alternatives. We found that the only case in which previous frequency of use was predictive of an alternative being selected was the Address Bar, which is a component of Windows that is not visible by default, and was thus very infrequently used by our participants. Its low previous usage suggests that participants may have previously expected up-front costs to learn to use the Address Bar.

Though previous frequency of usage had no impact on their choices, on the post-session questionnaires, several participants specifically alluded to the costs of learning new alternatives that were not previously used. For example:

Q: Why do you usually use these ways <the ways you usually use>?

> *"Because that is how I learned and it is easy."*
>
> *"Because I am not familiar with other ways."*
>
> *"Easy to use."*

The responses suggest satisfaction with the current perceived cost-risk-benefit ratio of prior investment in learning, implying no need for additional learning investment. Overcoming this perception is a challenge to new techniques aimed at helping users to access a desired resource.

Additional evidence for participants' lack of enthusiasm for bearing this learning cost can be seen in Table 4 and Used in Chapter 6 - Section 6.1. Notice that about 90% of the alternatives that they used were alternatives that they knew about and 10% of alternatives that they used were the alternatives they did not know about. Out of the 7 alternatives that were not known but were used, 5 of them were the Address Bar alternative. The participants were not willing to try out new alternatives that they did not know about and this suggests that there was a consideration of learning cost in their decision making.

Not spending time to learn is a common theme in studies reporting on similar phenomena. For example, it has been observed that users often use inefficient strategies even when more efficient strategies exist [Carroll and Rosson 1987] and that inefficient strategies are used even by experts who valued efficiency [Bhavnani et al. 2000].

Learning time's dissuading power is also consistent with the Attention Investment Model. It suggests that users may be deterred by the cost of learning new features, even when they realize that such features may be better ways to access their resources, if the up-front cost of learning is seen as being too costly or too risky an investment of their time. As with all investments, there is a risk of low or nonexistent return (such as when a feature is not helpful or the user doesn't succeed in learning), thus potentially making the learning investment seem unattractive.

7.3 Behavior Modification Is Possible

Despite this, there was some surprising evidence of success at encouraging learning new alternative paths. In designing this experiment, we chose to enable the

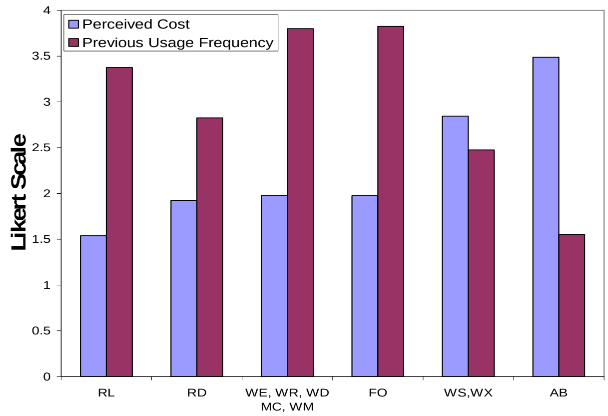


Figure 8: Popularity of Alternatives

Address Bar so that participants could use that alternative if they wanted. We did this by making the Address Bar visible at the bottom of the screen (in the Windows Task Bar) with its initial contents pointing to a folder on a local disk drive.

It turns out that this design choice had interesting consequences. In our study, 16 participants (41.02%) used the Address Bar. The mean number of file opens using this alternative for the 16 participants who used it was 31 (median 36), which amounts to 37% (median 43%) of the number of opens they made. In fact, 14 of these 16 participants used it for at least 18 file opens. Further, participants not only tried this alternative; they adopted it, making sustained use of the Address Bar alternative.

This is particularly interesting in light of the fact that this alternative was perceived to be the costliest. It had been least frequently used in the past (Figure 8). 5 out of those 16 participants who used it in the study reported that they *did not even know* that this alternative existed prior to the experiment. Clearly, for these 5 people, an incentive was present that was powerful enough to overcome resistance to new learning costs.

Discussion

The Address Bar may have made participants curious. Further, since the Address Bar already contained a default working destination, it visually explained how to use it, thereby implying low learning cost and low risk experimenting. Those who followed up were rewarded for its use: the necessary resource was accessed. Given a positive experience, they continued to use it throughout the experiment.

This trio — arousing curiosity, minimal explanations encouraging active experimentation and leading to reward — has led to success in other domains as well. For example, Surprise-Explain-Reward [Wilson et al. 2003] is a strategy that has been successfully used in software to attract users' attention to unfamiliar features. Just as with the Address Bar case, it attempts to arouse the user's curiosity about a potentially surprising new feature; he or she can then pursue invoking an action-encouraging explanation and, potentially, reap rewards. Our results corroborate empirical results of this strategy, suggesting that making a low-learning cost, high-reward alternative visible can motivate users to employ it, when they otherwise would not have even realized it existed.

8. Implications

8.1 Suggested Usage Of The Measuring Devices By Researchers And Designers Of Task-Centric Environments

This methodology allows precise measuring of costs for evaluating and reasoning about task-centric user interface environments.

***The state-transition model*:** For each available alternative, the state-transition model explicitly indicates the states that the user must traverse and the decisions they must make in order to achieve their goal of locating a resource. Because it is an analytical device only, it can be used "stand alone", and requires no technical set-up or specialized knowledge. A researcher or designer can use this model, even without the measuring devices, in the following ways:

- The existing model can be walked through to calculate order statistic figures to users (i.e., number of operations) of all the existing alternatives. These figures can serve as estimators for the costs to users of existing alternatives.
- Adding new alternatives to the state-transition model allows user costs of the new alternatives to be calculated.

***The first measuring device (actual user costs)*:** This device can be used to gather detailed information about what users actually do and the associated costs. The device requires technical set-up to make sure all the data is being collected reliably, and specialized follow-up in analyzing the data due to its volume and nature. In the context of user studies, the actual costs (in seconds) of each alternative used can then be gathered. This can be used to investigate "in usage" issues. For example:

- Analysis of consistency of a particular device's costs to users in actual usage.
- It provides a way to track and compare users' traversal through state space with a particular device, to see exactly how they are using it and, if they are

not using it wisely, where they may need indicators that will help them make better choices.

***The second measuring device (optimal user costs)*:** This device brings the theoretical costs of each available alternative (from the state-transition model) together with the choices and costs a user actually experiences in the context of a user study. It uses state information and the model to find the alternatives available to the user that they did not follow, and calculates the cost (in seconds) of these available alternatives. It works in partnership with the first measuring device, and likewise requires technical set-up and specialized follow-up. The device allows investigation of "best cost" issues such as:

- Theoretical best-case costs derived from the model alone to be "tested", by taking the number of seconds and having real users test-drive those paths to see if they can achieve that number of seconds.
- Investigation of situations in which users consistently deviate from better alternatives.
- Computation of which alternatives are best from a user cost standpoint, given the situations (states) users actually get into.

***The third measuring device (perceived user costs and choices)*:** This device does not require technical set-up or specialized follow-up; it is simply a questionnaire. Its primary usage is:

- It allows researchers and designers to obtain the user's opinion of the costs of the alternatives they know about. This information may be critical, because there is some evidence that users' cost-risk-benefit decisions are based in part on these costs—the *perceived* ones (which include perceived learning costs and perceived cost of choosing an alternative)—not on actual costs.

The model and three measuring devices can be used in the context of usability studies (as we have already done) or field studies. Thus, it enables design decisions to be made based on users' choices and their cost-risk-benefit analysis for actual and perceived usage. It also enables ongoing evaluation of new alternatives being developed to reduce user costs.

8.2 Implications of the Results

The results of this experiment are a set of findings with strong implications for systems aiming to support users in finding and accessing local task-specific resources.

- *Staying with only a small number of ways*: Users tend to stick to their preferred ways. (Only 11 of the 27 possible alternatives were chosen across all participants during the study, and almost all individual users only used two to three different alternatives.) This makes sense, because when there are a lot of choices to consider, a user is not likely to bear the mental cost of considering them all. This implies that it will be a challenge to attract users to a new alternative.
- *Constellations and anti-constellations:* The ways a user actually uses seem to group into "constellations," some of which appear to be application-centric, and others "Explorer-centric." For example, one such constellation was that users tended to use Windows Explorer or File Open Dialog (FO) together with Recent List (RL) in that application. There are also "anti-constellations": certain ways that users never seem to use together. The constellations and anti-constellations may help to explain why participants stayed within a small set of alternatives. This in turn suggests that breakthrough new ways that might be developed still may never or rarely be used, if they do not fit well in an existing constellation or catalyze a new one.

Things that don't seem to help:

- *An alternative's cost versus being selected*: The ways that users tend to choose to access files are not necessarily the most efficient ones, or even perceived to be the most efficient ones. In particular, perception of low cost is not enough for an alternative to join a user's group of favorite ways.

- *Role of computer experience in determining cost:* Users do not get faster at accessing local resources with computer experience: computer experience had no relation to the performance of accessing resources. This underlines the importance of helping to reduce these costs, since they are not a temporary phenomenon that goes away after the user gains experience.
- *Search tools*: Searching was not very popular. It is possible that an alternative search tool might have been more popular than the (widespread) ones that were present in our experiment, but we believe that is somewhat unlikely: previous research has indicated that users in fact prefer manual browsing to searching. Also, the actual costs of the manually locating alternatives in our experiment were much lower (and less variable) than alternatives that involved searching.

Things that do seem to help:

- *Very fine-grained feedback*: It has been established in the literature that users appreciate iterative, interactive feedback, and this seemed to be evident in their choice in locating files. Windows Explorer was very attractive to participants, which is consistent with previous findings which revealed that participants preferred strategies that gave interactive feedback about their current status and progress towards locating a file at every step along the way.
- *Surprise-Explain-Reward:* It appears that the perceived cost and risk of learning new alternatives may have outweighed participants' sense of the cost and benefit improvements of actually using them. This is consistent with similar results by others (the paradox of the active user). However, it appears to be possible to modify behavior from a user's pattern, by attracting them to lower-cost alternatives through an instantiation of the Surprise-Explain-Reward strategy. A critical aspect seems to be to alert users to the presence of an alternative that appears to have a low learning cost and risk, and which turns out to also deliver low actual cost.

9. Conclusion

In this thesis, we have presented a methodology for investigating ways and costs for users' local resource access, including a detailed model of possible alternatives and cost structures. Using this methodology, we conducted an empirical study to shed light on the roles of different kinds of costs on users' behavior.

We described three measuring devices that were motivated by our methodology, which we then instantiated to measure alternatives and costs of resource access: a measuring device for collecting chosen alternatives and their cost, a measuring device for available alternatives and optimal cost, and a measuring device for participant-reported alternatives and costs.

The costs we investigated were inspired by the Attention Investment Model. We learned that actual costs in these circumstances were related to optimal costs, which showed that users were motivated by reducing their costs of day-to-day operation. However, the relationship was not strong enough to explain many of their choices, and in fact even perceived costs were not significant predictors of users' choices. Instead, the amount and risk of the up-front investment seemed to outweigh the ongoing cost. This was seen in participants' aversion to incurring possible learning costs and risks as well as in their avoidance of the up-front costs of considering a large number of alternatives: they used only two or three favorite options, even when they were familiar with many more.

These results reveal that implicit assumptions that may underlie some of the research into improving these costs do not hold. In particular, since our participants considered only a small fraction of the 27 alternatives possible, the evidence does not support the notion that users will voluntarily even consider such research's emerging 28th alternative, let alone learn how to use it.

Thus, three challenges must be faced by emerging technological devices to reduce resource access costs for users: (1) how to make users aware of these new alternatives in a way that does not increase their already too-high up-front costs; (2) how to communicate low learning cost and low risk of new alternatives — so low that the user will be willing to try them; and (3) how to maximize the chances that a user's initial experimentation with new alternatives will indeed deliver on its promise of low ongoing cost, so that the user's up-front costs will pay off.

Bibliography

[Bannon et al. 1983] Bannon, L., Cypher, A., Greenspan, S., Monty, M. Evaluation and analysis of users' activity organization. *Proc. CHI*, ACM Press (1983), 54–57.

[Barreau et al. 1995] Barreau, D., Nardi, B. Finding and reminding: File organization from the desktop. *SIGCHI Bulletin*, 27(3), ACM Press (1995), 39–43.

[Bellotti et al. 2003] Bellotti, V., Ducheneaut, N., Howard, M., Smith, I. Taking email to task: The design and evaluation of a task management centered email tool. *Proc. CHI*, ACM Press (2003), 345–352.

[Bhavnani et al. 2000] Bhavnani, S.K., John, B.E. The strategic use of complex computer systems. *Human–Computer Interaction* (2000), 15(2-3), 107–137.

[Blackwell 2002] Blackwell, A. First steps in programming: A rationale for attention investment models. *Proc. Symp. IEEE Human-Centric Computing Languages and Environments* (2002), 2–10.

[Boardman and Sasse 2004] Boardman, R. and Sasse, M.A. Stuff goes in the computer but it doesn't come out: A cross-tool study of personal information management, *Proc. CHI*, ACM Press (2004), 583-590.

[Boardman et al. 2003] Boardman, R., Spence, R., Sasse, M.A. Too many hierarchies? The daily struggle for control of the workspace. *Proc. HCI International 2003*, (1), 616–620.

[Bruce et al. 2004] Bruce, H., Jones, W., Dumais, S. Information behaviour that keeps found things found. *Information Research* (2004), 10(1).

[Card et al. 1980] Card, S.K., Moran, T.P., Newell, A. The keystroke-level model for user performance with interactive systems, *Comm. ACM*, 23(7), ACM Press (1980), 396–410.

[Carroll and Rosson 1987] Carroll, J.M., Rosson, M.B. Paradox of the active user. In J. M. Carroll (Ed.), *Interfacing Thought*: *Cognitive Aspects of Human–Computer Interaction*. MIT Press (1987), 80–111.

[Czerwinski et al. 2004]Czerwinski, M., Horvitz, E., Wilhite, S. A diary study of task switching and interruptions. *Proc. CHI*, ACM Press (2004), 175–182.

[Dourish et al. 1999] Dourish, P., Edwards, K.W., LaMarca A., Salisbury, M. Presto: An experimental architecture for fluid interactive document spaces. *ACM Trans.Computer-Human Interaction*, 6(2), (1999), 133–161.

[Dragunov et al. 2005] Dragunov, A.N., Dietterich, T.G., Johnsrude, K., McLaughlin, M., Li, L., Herlocker, J.L. TaskTracer: A desktop environment to support multi-tasking knowledge workers. *Proc. IUI*, ACM Press (2005), 75–82.

[Freeman et al. 1996] Freeman, E., Gelernter, D. Lifestreams: A storage model for personal data. *In SIGMOD Record*, 25(1), ACM Press (1996), 80–86.

[Fu and Gray 2004] Fu, W., Gray, W. D. Resolving the paradox of the active user: Stable suboptimal performance in interactive tasks. *Cognitive Science* (2004), 28(6), 901-937

[Gonzalez et al. 2004] Gonzalez, V., Mark, G. "Constant, constant, multi-tasking craziness": managing multiple working spheres. *Proc. CHI*, ACM Press (2004), 113–120.

[Henderson and Card 1986]Henderson, A., Card, S. Rooms: The use of multiple virtual workspaces to reduce space contention in a window-based graphical user interface. *ACM Transactions on Graphics 1986*,5(3), ACM Press (1986), 211–243.

[Horvitz et al. 2003] Horvitz, E., Kadie, C., Paek, T., Hovel, D. Models of attention in computing and communication: from principles to applications. *Comm. ACM*, 46(3), ACM Press (2003), 52–59.

[Jones et al. 2005] Jones, W., Phuwanartnurak. A.J., Gill, R., Bruce, H. Don’t take my folders away! Organizing personal information to get things done. *In Ext. Abstracts CHI*, ACM Press (2005), 1505–1508.

[Kaptelinin 2003] Kaptelinin, V. UMEA: Translating interaction histories into project contexts. *Proc. CHI*, ACM Press (2003), 353–360.

[Kaptelinin 1996] Kaptelinin, V. Creating computer-based work environments: An empirical study of Macintosh users. *Proc. ACM SIGCPR/SIGMIS*, ACM Press (1996), 360–366.

[Malone 1983] Malone, T. W. How do people organize their desks? Implications for the design of office information systems. *ACM Trans. Information Systems*,1(1), ACM Press (1983), 99–112.

[Ravasio et al. 2004] Ravasio, P., Schar, S., Krueger, H. In pursuit of desktop evolution: User problems and practices with modern desktop systems. *ACM Trans. Computer-Human Interaction*,11(2), ACM Press (2004), 156–180.

[Rekimoto et al. 1999] Rekimoto, J. Time-machine computing: A time-centric approach for the information environment. *Proc. UIST*, ACM Press (1999), 45–54.

[Ringel 2003] Ringel, M. When one isn't enough: an analysis of virtual desktop usage strategies and their implications for design. In *Ext. Abstracts CHI 2003*, ACM Press (2003), 262–263.

[Robertson et al. 1998] Robertson, G., Czerwinski, M., Larson, K., Robins, D.C., Thiel, D., von Dantzich, M. Data Mountain: Using spatial memory for document management. *Proc. UIST*, ACM Press (1998), 153–162.

[Smith et al. 2003] Smith, G., Baudisch, P., Robertson, G., Czerwinski, M., Meyers, B., Robbins, D., Andrews, D. GroupBar: The taskbar evolved. *Proc. OZCHI* 2003.

[Teevan et al. 2004] Teevan, J., Alvarado, C., Ackerman, M.S., Karger, D.R., The perfect search engine is not enough: a study of orienteering behavior in directed search. *Proc. CHI*, ACM Press (2004), 415–422.

[Wilson et al. 2003] Wilson, A., Burnett, M., Beckwith, L., Granatir, O., Casburn, L., Cook, C., Durham, M., Rothermel, G. Harnessing curiosity to increase correctness in end-user programming. *Proc. CHI*, ACM Press (2003), 305–312.

APPENDICES

Appendix A: Tutorial

Introduction

Hi, my name is Vidya Rajaram, and I will be leading you through today's study.The other people involved in the study are Dr.Margaret Burnett, Dr.Jon Herlocker, Dr.Simone Stumpf, Kevin Johnsrude, Anton Dragunov, Julie Lynn and the assistants helping me out today.

I will be reading through this script so that I am consistent in the information that I provide you and the other people taking part in the study for scientific purposes.

The purpose of this study is to investigate the patterns that users follow when they interact with computers, and, in particular, to understand the cost (in terms of low-level user actions as well as more high-level costs such as cognitive operations) of activities that can be reduced or avoided with Task Tracer — the software package developed by our research group.

For today's experiment I will lead you through a brief tutorial after which you will take a few experimental tasks. Please do NOT discuss this study with anyone. We are doing later sessions and we would prefer the students coming in not to have any advance knowledge.

Anybody who hasn’t returned the Informed Consent form and the Background Questionnaire, please raise you hand.

(After they raise hands)

Please fill the forms and raise you hand. The assistants will collect it from you.

If you have any questions, please contact

Contact:

- Dr.Margaret Burnett burnett@eecs.oregonstate.edu

Any other questions maybe directed to the IRB Coordinator, Sponsored Programs

Office, OSU Research Office,(541)737-8008

The contact addresses are available in the "Informed Consent" form that you have with you.

Tutorial

Before we begin, I would like to tell you not to check personal emails or work on anything else that is not related to the experiment. Also, do not use Internet explorer or any other browser. And please raise your hand if you have any problems and the assistants will help you out.

As we go through this tutorial, I want you to ACTUALLY PERFORM the steps I'm describing. Erin will be demonstrating in the screen. So if you have any doubts, please look at the screen.

Now I will explain to you how the experiment is structured. There are some files in your system related to NASA (National Aeronautics and Space administration).

There will be a folder called NASA available on your system in the location "C:\temp\Documents". This location is available in the **"location sheet"** that has been handed out to you. Now let us go to that location to view the folder. Please go to the location "C:\temp\Documents". Here you can see the folder NASA.

Now open that folder. ***(Wait for them to click)***

You can see that this folder contains a number of subfolders like “Budgets”, ”Fun for Kids”, “Missions” etc.

(Erin will just mouse over the folders)

In the folder “Budgets”, you can find information related to Budgets of NASA. In the folder “Fun for Kids”, you can find information about what kids events are being organized in NASA. Similarly all other folders contain information about NASA.

Now Let us move these folders to different locations. I want you to move the folders to the locations I ask you to. Please don’t copy them but move them to the destination. The location sheet which you have contains the destinations to which you need to move the folders to.

For example, move the folder **“News-Events-Features”** at the location **“**c:\temp\Documents\NASA” to the location “c:\temp\Documents\Things going on at NASA”.

Please raise you hands after you finish moving the folders.

- **Move folder “c:\temp\Documents\NASA\News-Events-Features” to “c:\temp\Documents\Things going on at NASA”.**
- **Move folder “c:\temp\Documents\NASA\Missions” to “c:\temp\Documents\Things going on at NASA”.**
- **Move folder “c:\temp\Documents\NASA\People of NASA” to “c:\temp\Documents\Jobs at NASA”.**
- **Move folder “c:\temp\Documents\NASA\Want to be a part of NASA” to “c:\temp\Documents\Jobs at NASA”.**

- **Move folder “c:\temp\Documents\NASA\NASA Facts” to “c:\temp\Documents\Interesting Facts”.**
- **Move folder “c:\temp\Documents\NASA\Outerspace Facts” to “c:\temp\Documents\Interesting Facts”.**
- **Move folder “c:\temp\Documents\NASA\Fun for kids” to “c:\temp\Documents\Things to do at home with your kids”.**
- **Move folder “c:\temp\Documents\NASA\Proposals” to “c:\temp\Documents\NASA Grants”.**
- **Move folder “c:\temp\Documents\NASA\Budgets” to “c:\temp\Documents\Where NASA’s money goes”.**

(Assistants will check if they moved the folders and delete the NASA folder).

Now lets go to “**C:\temp\Documents\Where NASA’s money goes**” . Here you can see a folder called “Budgets”. Please open the folder “Budgets”.

(Erin should have the folder open already)

This folder contains some Microsoft Excel files 02-06. These files refer to the budget information of NASA in the different years. Now, please open the file “04.xls”, ***(wait for them to open. Erin will already have this open)*** you can see information about how much budget was requested in the year 2004 for the different space operations.

(Erin will have the file open and she will mouse over the contents)

Now please close the file “04.xls”. ***(Wait for them to close the file)***

Similarly you can find different information about NASA in the various folders.

Now please take a couple of minutes to browse through the files in **“C:\temp\Documents”** to **familiarize yourself** with the NASA content.

(Wait a couple of minutes for them to browse through the folders. No demonstration required).

Practice Task

Now let us go on to the practice task. In this task, you will be presented with a set of questions one after the other. Now please look at the screen. You will see a quiz box like this. This quiz box has a question and a text box for you to type the answer. Some questions will be multiple choice and some questions will require you to type in the answer in the text box provided. Once you type the answer you will have to hit the OK button. You cannot pass any question.

(Erin will have this open already and will bring up the question popping box. Erin will also have the answer file open)

All the questions are about NASA. Your goal is to answer the questions correctly. The answers to ALL the questions can be obtained from the files in **"C:\temp\Documents"**.

For example, in this question "How many activities are available for kids?" This is where Erin got the answer from. Type in the answer in the text box.

(Erin shows the file and types in the answer in the question popping box)

So after you answer the question, please click on the "OK" button. Once you hit the "OK" button, some windows and the some documents that were open will be closed automatically.

For example, please look at the screen.

(Have some windows open already so that we don't create any bias in the way the file is opened. Erin will click on the OK button).

The answers to most of the questions will require information from multiple Word documents and Excel workbooks. So you might have to look up multiple files to answer a single question.

Take you own time to answer the questions. Please try to answer as many questions as possible correctly.

Now the assistants will bring up the quiz box for you. Please DO NOT start until I ask you to.

(Assistants will bring up the question popping box and tell them not to close the command prompt)

Now you can start you practice tasks. I will tell you when you need to stop.

(About 10 minutes)

Now we are finished with the practice task.

Assistants will now close down the quiz box.

(Assistants will close down the question popping s/w and take away the 'cheat sheet')

Main Task

Let us proceed to the main experiment. This will be similar to the practice task. You will be presented with a set of questions one after the other. You will have to find the answers to these questions from the files in the location **"C:\temp\Documents".**

You might need to look up multiple files in order to answer one single question. You cannot pass any questions. After answering the questions hit on the "OK" button. When the OK button is clicked, some of the open windows and documents will get closed down automatically.

Interruptions

There are some questions on which you will be interrupted. That is while working on certain questions, a new question will be popped up preventing you from finishing the question you had been working on. When the new question pops up, some of the windows and some documents that are opened will be closed automatically. These interrupted questions may or may not appear again in the quiz.

I would like to remind you again not to check any personal emails or work on any other stuff not related to the experiment. As I've said before, do not use Internet explorer or any other browser. Do not use web search to obtain answers for the questions. Answers to all questions can be obtained from the files in the location "C:\temp\Documents".

The assistants will bring up the quiz box for you. Please DO NOT start until I ask you to.

(Assistants will bring up the question popping software and tell them not to close command prompt).

So now you can start the main task. I will tell you when you need to stop.

(Experiment Begins)

(About 40 minutes)

(Experiment ends)

The main task is over.

Post-Session Questionnaire

(Hand out Post-session questionnaire and ask them to fill it out).

Now I would like you all to fill out the questionnaire that is being handed out to you.

(Collect the questionnaire back). This should roughly take about 10 minutes. Please raise your hand once you have finished and the assistants will collect the forms from you.

Please DO NOT touch the computer anymore.

(After collecting all forms)

Now you will need to sign the receipt and collect your money from Simone.

(Hand out receipt and pay them).

Thank You

I would like to thank you all for participating in the experiment and being very cooperative. I will be very happy to answer any questions you have. Once again I would like to thank you all on behalf of the Task Tracer team.

Appendix B – Tasks

The following questions were given to the participants as part of a quiz task. The answers were to be obtained from a set of Word documents and Excel spreadsheets provided to them.

1. What is the nickname of the flight director who is standing second from right in the back row in the group photo?

    Answer: Bob

2.How much budget was requested for Lunar Exploration in 2005?

    Answer: 70

3. Where will the national space day celebration be held?

    Answer: Virginia at the National Air and Space Museum's Steven F. Udvar-Hazy Center

4. In the flight directors group photo there is a person sitting second from right in the front row. In which mission centre is her individual photo taken?

    Answer: Shuttle (White) Flight Control Room in Houston's Mission Control Center.

5. On which date was the news 'hubble celebrates 15th anniversary'published?

    Answer: 04.25.05

6. There are 8 parts in the grant proposal. What is the 3rd part about?

    Answer: Project Description

7. There is an individual photo of a flight director whose last name is Ridings. Where is he/she in the group photo? Specify: row - number - direction.

    Answer: front_2nd_left

8. How much budget was requested for Biological and Physical research in 2004?

    Answer: 973

9. In the memory game for kids where do the two friends go?

Answer: Saturn

10. On which date was the flight directors' group photo taken?

Answer: 11 February 2005

11. In which year was the Budget requested for SOLAR SYSTEM EXPLORATION the greatest?

Answer: 2004

12.What is the name of the kid who did the deep impact coloring page?

Answer: Diana

13.For the vehicle launched on 4th May how many configurations were taller than 70m?

Answer: 1

14. How old was the boy who wrote the poem 'The boy's first flight'?

Answer: 9

15.In which year was the budget requested for Education the highest?

Answer: 2005

16. What is the name of the spaceship in one of the kid's stories?

Answer: Atlantis

17.Administrative and Management constitute what % of Nasa's positions?

Answer: 24

18.There are 8 parts in the grant proposal. What is the 6th part about?

Answer: Facilities and equipment

19. The individual photos of how many flight directors are available?

Answer: 3

20. When was NASA started?

Answer: 1958

21. Was the budget requested for Constellation systems greater for 2004 than in 2005?

Answer: yes

22.How many flight directors are standing in the group photo?

Answer: 5

23. In which year did Human Research Technology require maximum budget?

Answer: 2005

24. The research news on 02/08/05 is about a conference. Who opened this conference?

Answer: Dr. Adena Loston

25. The activity taught by a girl required how many items?

Answer: 11

26. How many days after the flight directors' group photo was taken were the individual photos taken?

Answer: 14

27.How much budget was requested for Mars Exploration in 2005?

Answer: 690.9

28.According to Sally K.Ride's advice for high school students NASA recruits people with which of the following backgrounds? a.History Of Science, b.Microbiology, c.International studies, d.Psychology

Answer: Microbiology

29.How many questions are there in the 'Questions and Answers'?

Answer: 11

30.NASA uses a tool for recruting. When was the company that founded this tool started?

Answer: 1988

31. How much budget was requested for Kepler development in 2005?

Answer: 127.2

32.How many MEN are there in the flight directors group photo?

Answer: 6

33.In which year was the budget requested for Space science the greatest?

Answer: 2004

34.In Nasa's team who is the Chief Financial Officer?

Answer: Gwendolyn Sykes

35.In one of the activities a boy wrote the story Going to NASA. According to the story what had fallen on him in the middle of the night?

Answer: bulletin board

36.When is/was the Earth System Science Fellowship proposal due?

Answer: 01-Jun-2005

37. There is a flight director whose individual photo has been taken at Shuttle (White) Flight Control Room in Houston's Mission Control Center. Where is he/she standing in the group photo? Specify: row -number -direction.

Answer: back-3rd-right

38. In which year was the budget requested for Aeronautics technology the smallest?

Answer: 2006

Appendix C – Questionnaires

BACKGROUND QUESTIONNAIRE

1. Subject Number ____________________________

2. Gender ☐ M ☐ F

3. What is your Major? ____________________________

4. Year or degree completed
   - ☐ Freshmen
   - ☐ Sophomore
   - ☐ Junior
   - ☐ Senior
   - ☐ PostBac
   - ☐ Graduate student

5. Cumulative GPA (roughly) ____________________________

6. IS ENGLISH YOUR PRIMARY LANGUAGE ☐ Yes ☐ No

   If not, how long have you been speaking English? ______________ years

7. What have you used computers for? (please check all that apply)

- ☐ For high school — How many years? ______________
- ☐ For college — How many years? ______________
- ☐ For professional use — How many years? ______________
- ☐ For personal use — How many years? ______________

8. Do you own a computer? ☐ Yes ☐ No

9. Do you use university computer labs? ☐ Yes ☐ No

10. Which do you use more? ☐ Own Computer ☐ University computer

11. What account do you use most frequently to access university computers (e.g., ONID, ENGR, Forestry etc.)? ___________________________________

12. Which campus computer lab do you use most often (e.g., Milne, Hovland, Forestry,
Business, etc.)? ___________________________________

Subject Number:

POST SESSION QUESTIONNAIRE

1. Please check any one of the following:

	Low — High
MENTAL DEMAND How much mental and perceptual activity (e.g thinking, deciding, calculating, remembering, looking, searching etc.) was required to answer the questions?	☐ ☐ ☐ ☐ ☐
TEMPORAL DEMAND How much time pressure did you feel due to the rate or pace at which the questions appeared?	☐ ☐ ☐ ☐ ☐
PERFORMANCE How successful do you think you were in answering the questions?	☐ ☐ ☐ ☐ ☐
EFFORT How hard did you have to work (mentally or physically) to accomplish your level of performance?	☐ ☐ ☐ ☐ ☐
FRUSTRATION LEVEL How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel while answering the questions?	☐ ☐ ☐ ☐ ☐

2. How do you usually get to files in your system?

3. Besides the ones you listed above, do you ever use any other ways? If yes, what are they?

4. Why do you usually use the ways you gave in Question 2?

5. What helps you remember where your files are in the system?

6. Which was more difficult? (Choose one)

- ☐ Getting the right file
- ☐ Finding the information within the file

7. How do you store files that belong to more than one topic?
(For example, if you have payroll information about students, would you store it in Payroll folder, students folder, or both, or some other way?)

8. Are you familiar with the following ways to access files in MS Windows environment?

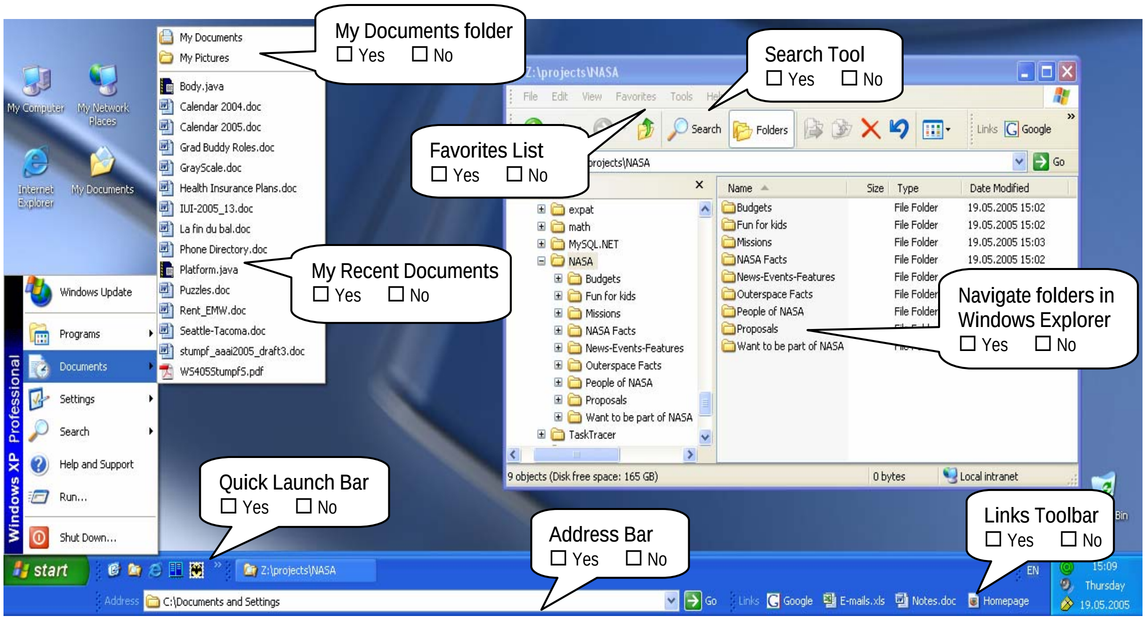


Figure 1a: Desktop Screenshot – Familiar Ways

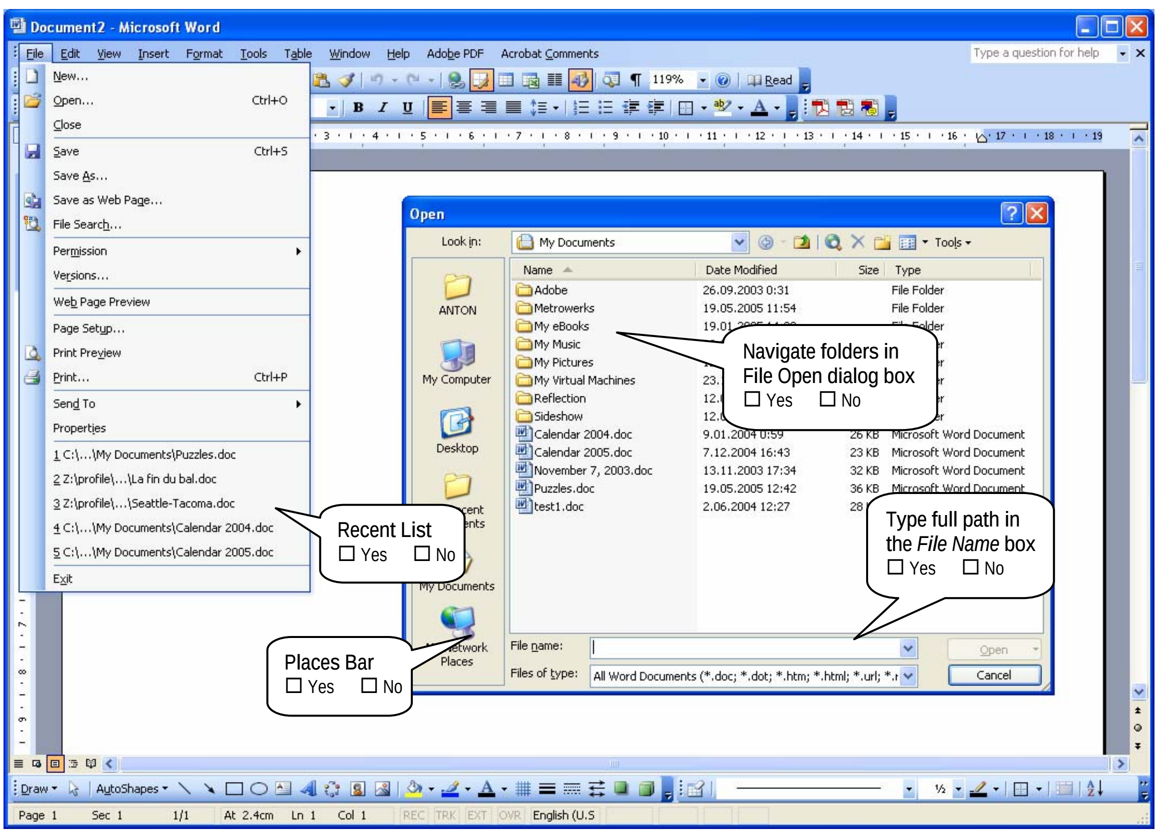


Figure 1b: Application Snapshot – Familiar Ways

9. How much work do you think it is to find the right files in the following ways (see picture)?

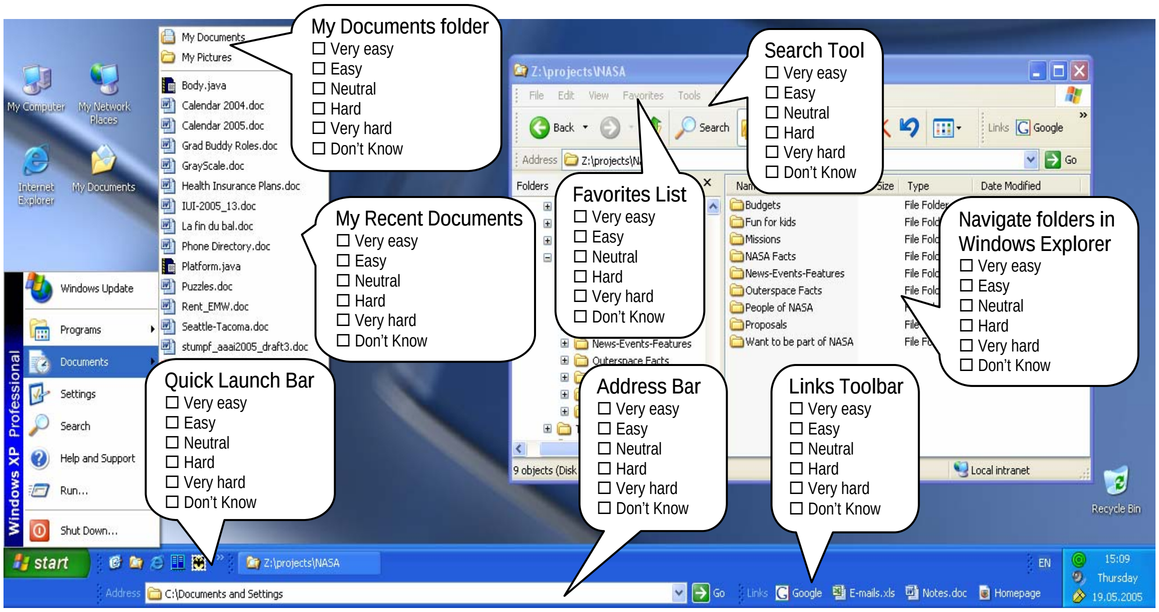


Figure 2a: Desktop Snapshot – Perceived Cost

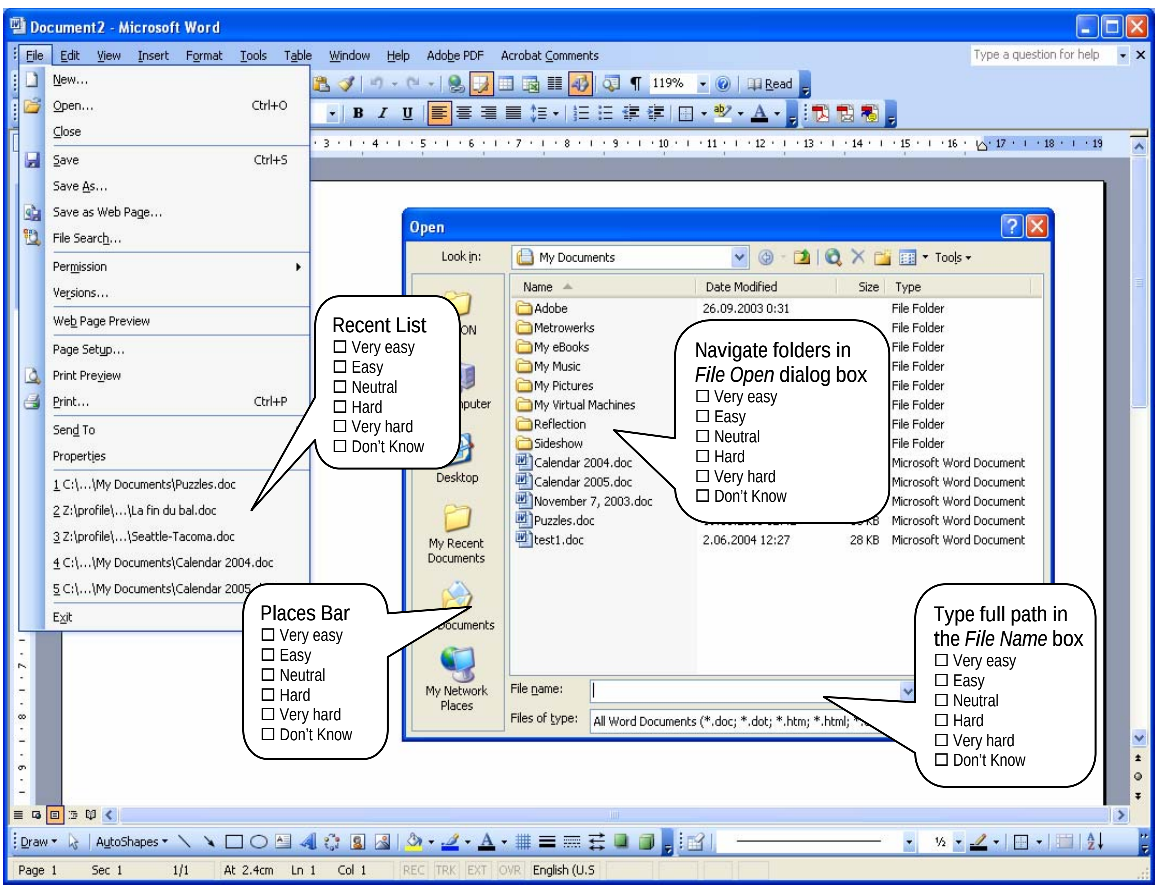


Figure 2b: Application Snapshot – Perceived Cost

10. How frequently do you use these different ways to get to files in MS Windows environment?

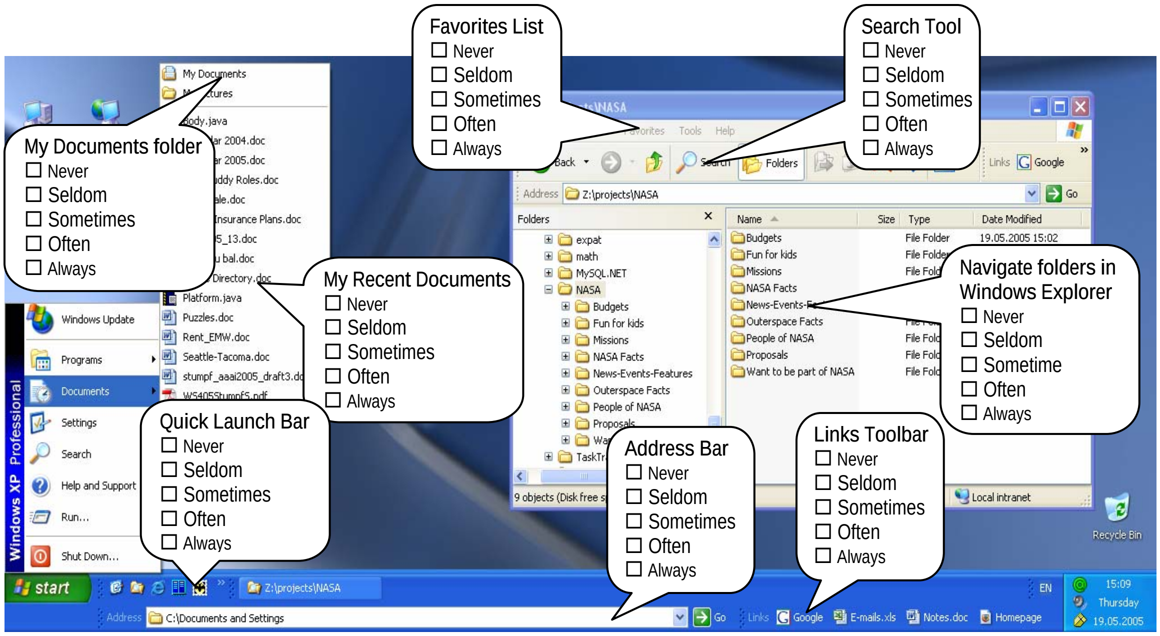


Figure 3a: Desktop Snapshot – Frequency of Use

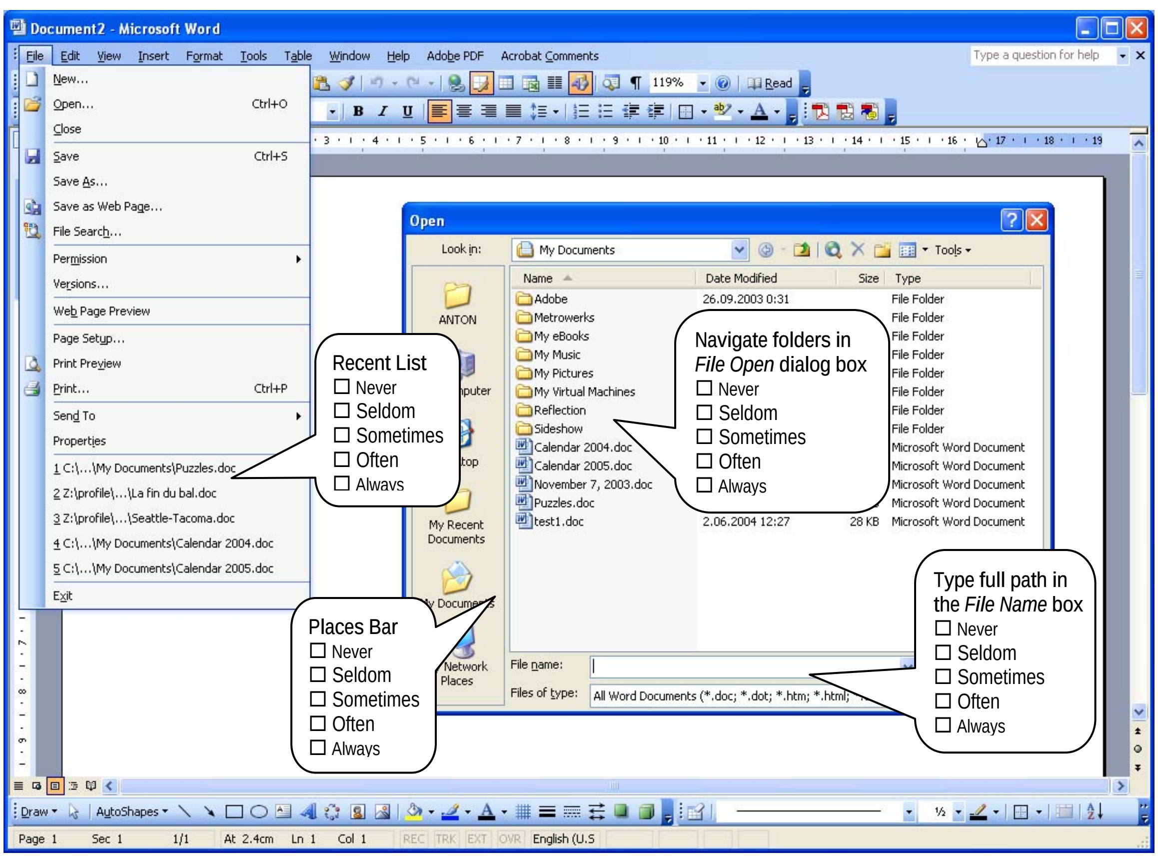


Figure 3b: Application Snapshot – Frequency of Use

11. Please check any one of the following, considering the interruptions.

	Low — High
MENTAL DEMAND How much mental and perceptual activity (e.g thinking, deciding, calculating, remembering, looking, searching etc.) was required when you were interrupted?	☐ ☐ ☐ ☐ ☐
FRUSTRATION LEVEL How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel when you were interrupted?	☐ ☐ ☐ ☐ ☐

THANK YOU

Appendix D – State Diagrams

1. Choose another alternative

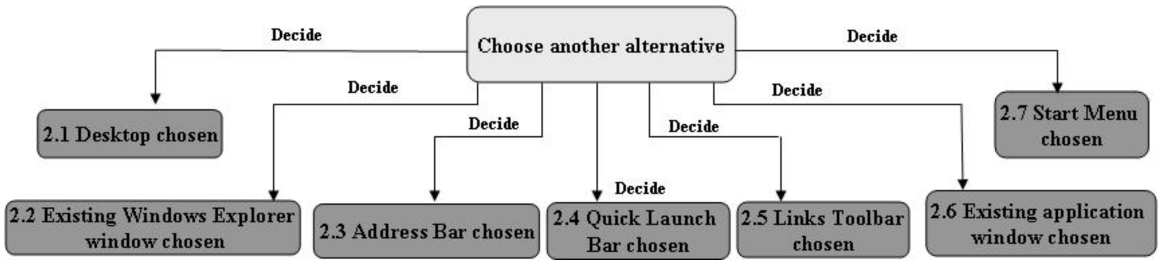


Figure 4: Choose an Alternative Path

2.1 Desktop chosen

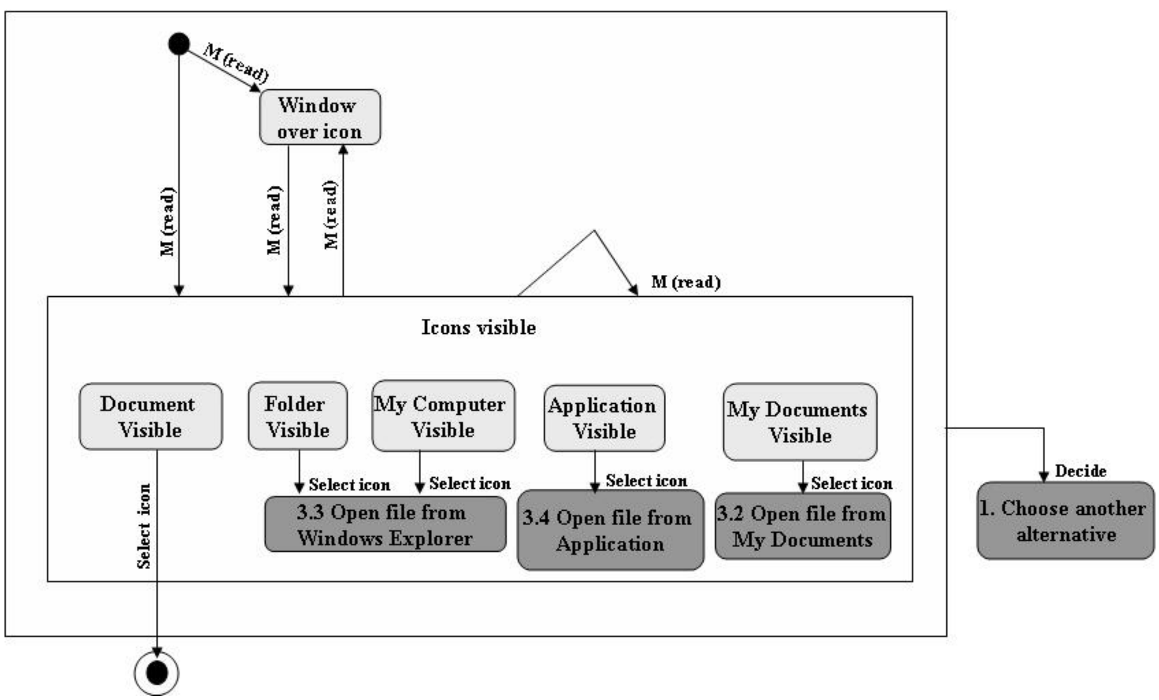


Figure 5a – Desktop Chosen

2.2 Existing Windows Explorer chosen

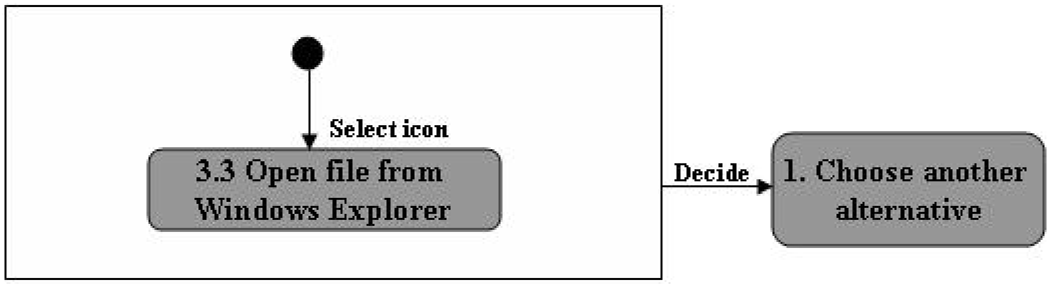


Figure 5b: Existing Window Explorer Chosen

2.3 Address Bar chosen

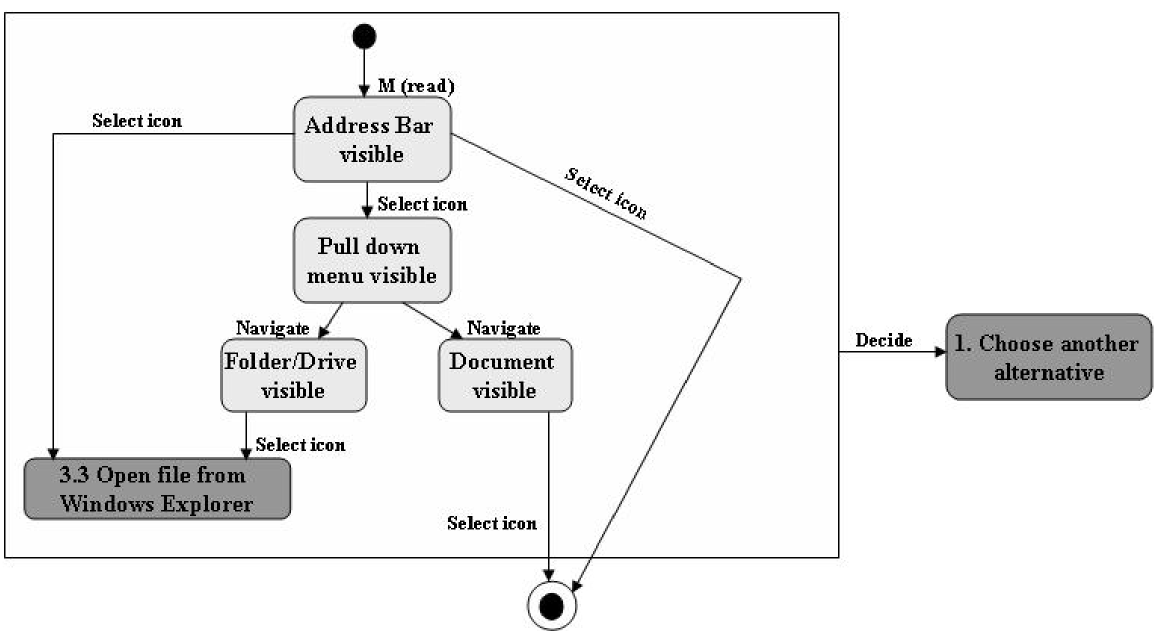


Figure 5c: Address Bar Chosen

2.4 Quick Launch Bar chosen

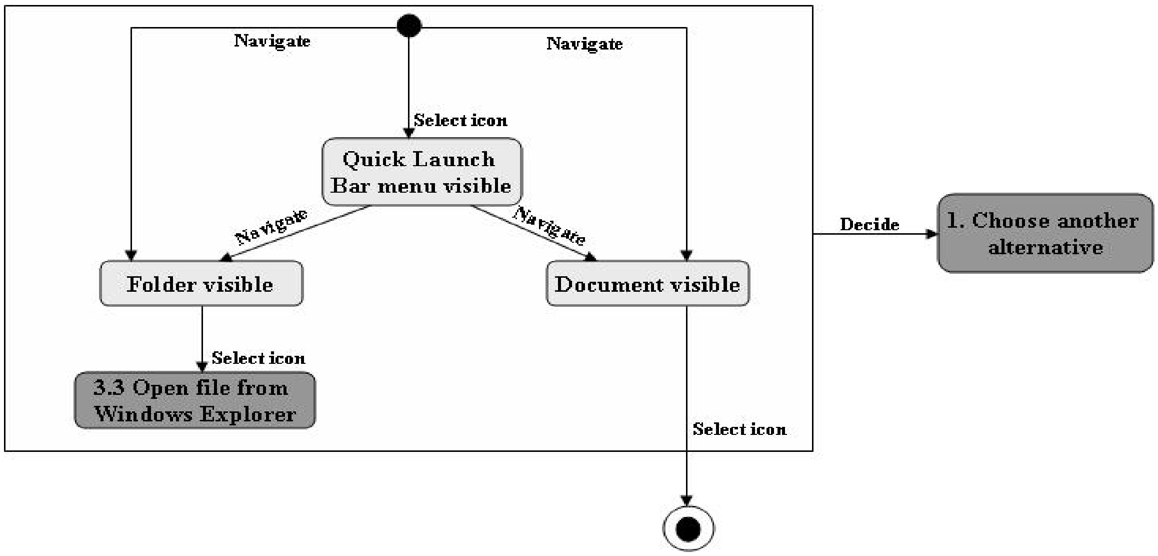


Figure 5d: Quick Launch Bar Chosen

2.5 Links Toolbar chosen

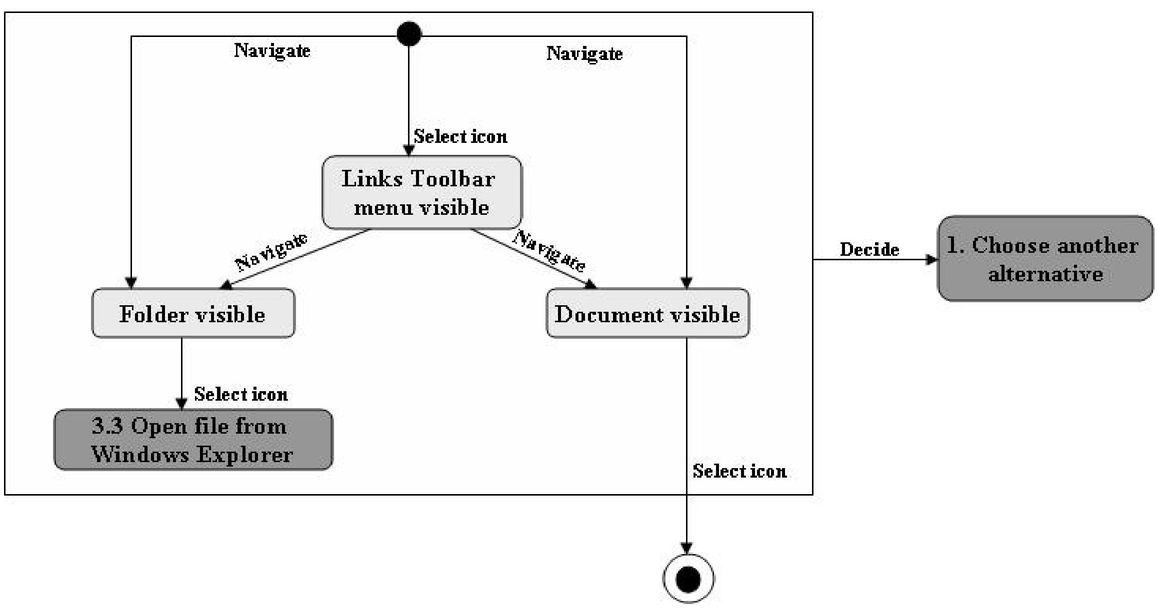


Figure 5e: Links Toolbar Chosen

2.6 Existing Application Window chosen

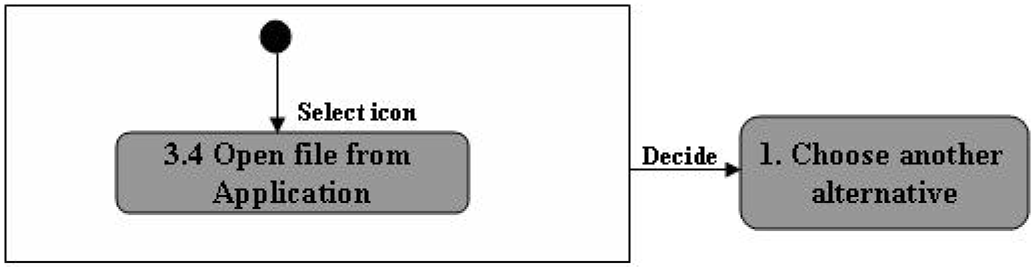


Figure 5f: Existing Application Window Chosen

2.7 Start Menu chosen

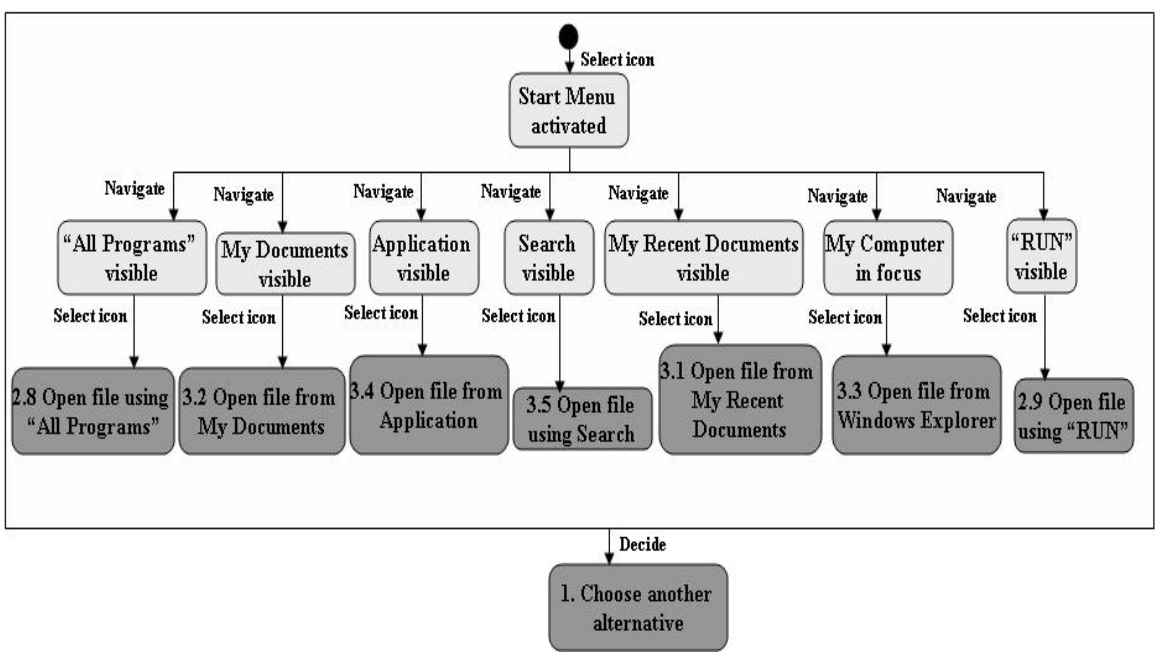


Figure 5g: Start Menu Chosen

2.8 Open Application from "All Programs"

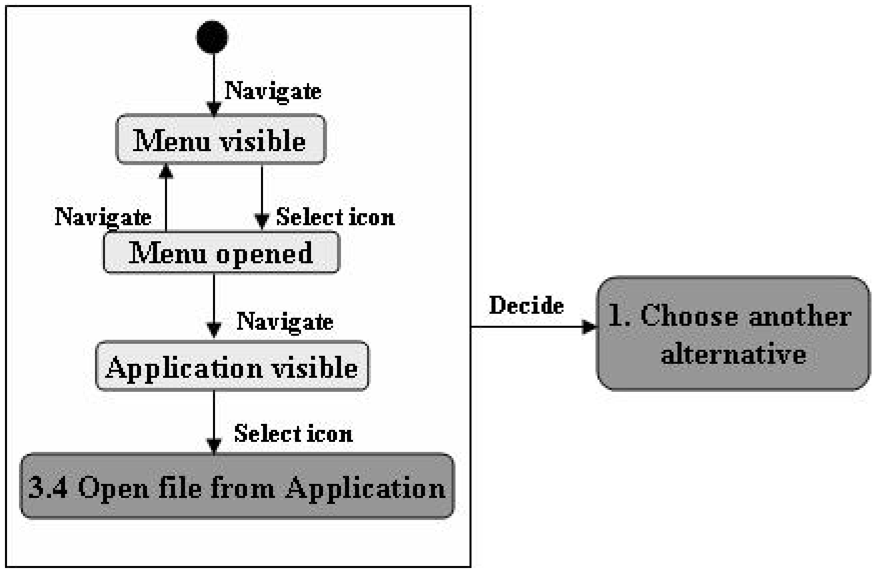


Figure 5h: Open Application from "All Programs"

2.9 Open file from "RUN"

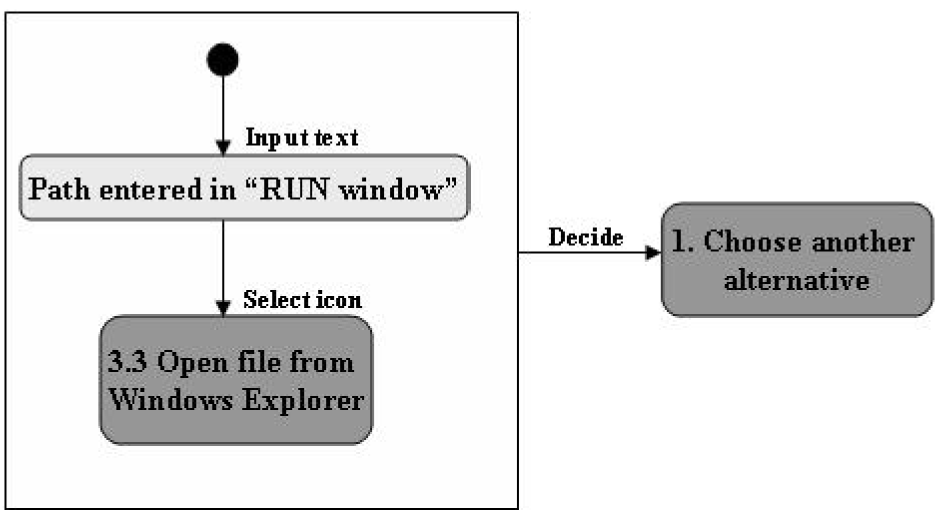


Figure 5i: Open File from "RUN"

3.1 Open file from My Recent Documents

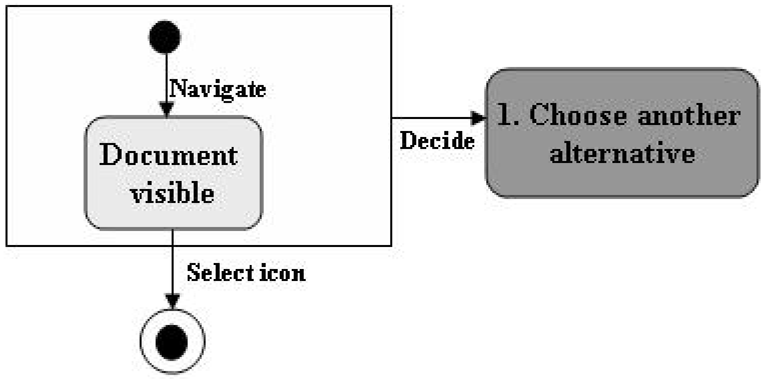


Figure 6a: Open File from My Recent Documents

3.2 Open file from My Documents

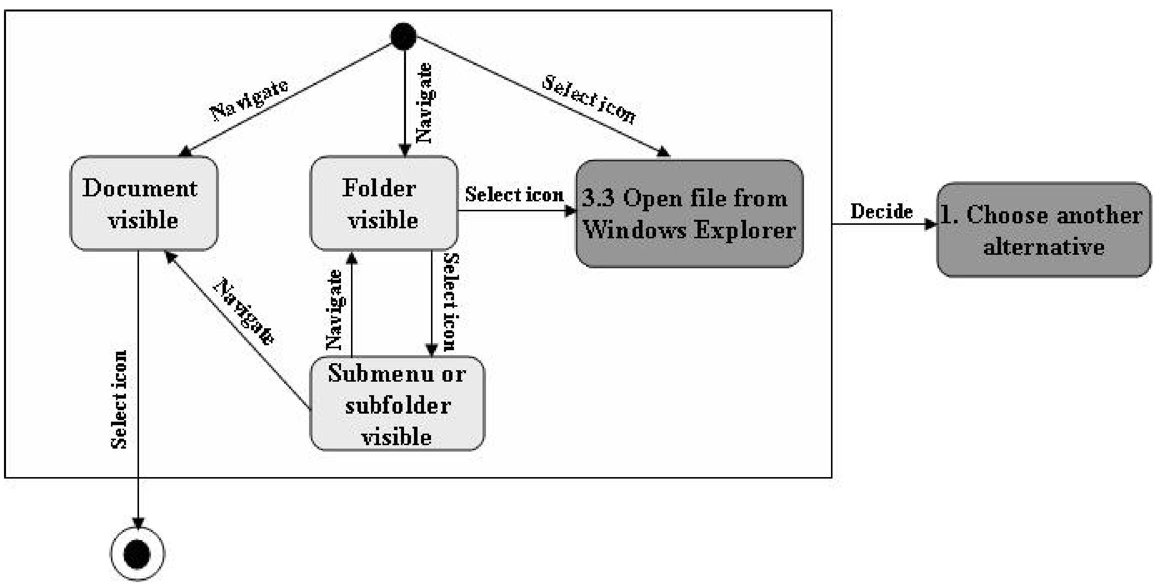


Figure 6b: Open File from My Documents

3.3 Open file from Windows Explorer

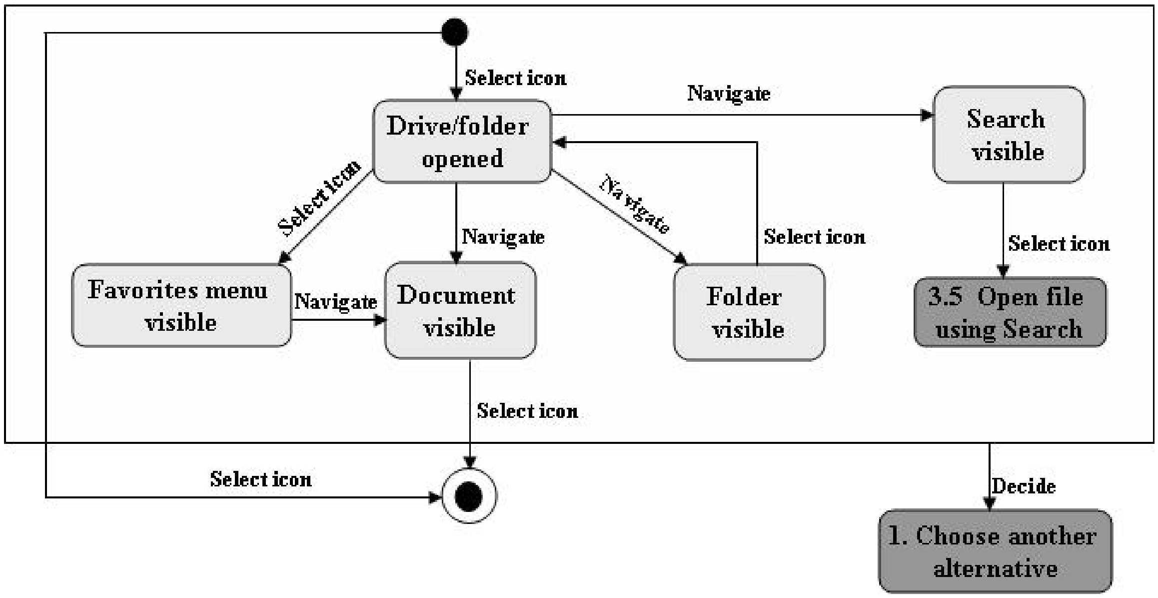


Figure 6c: Open File from Windows Explorer

3.4 Open file from Application

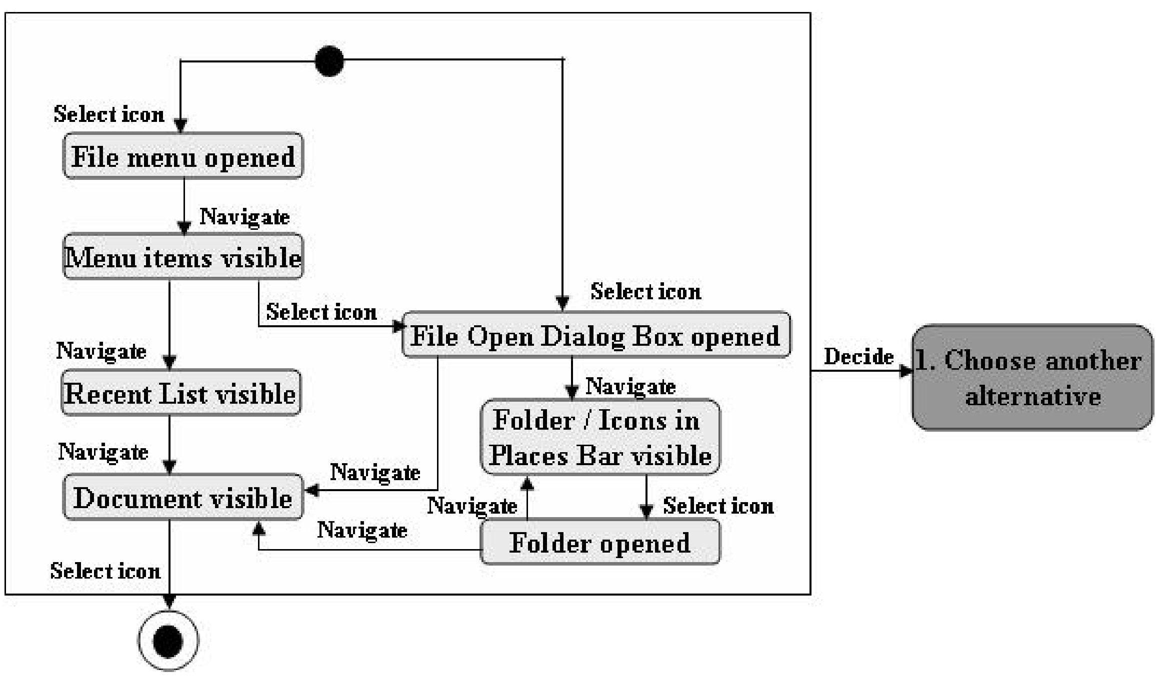


Figure 6d: Open File from Application

3.5 Open file using Search

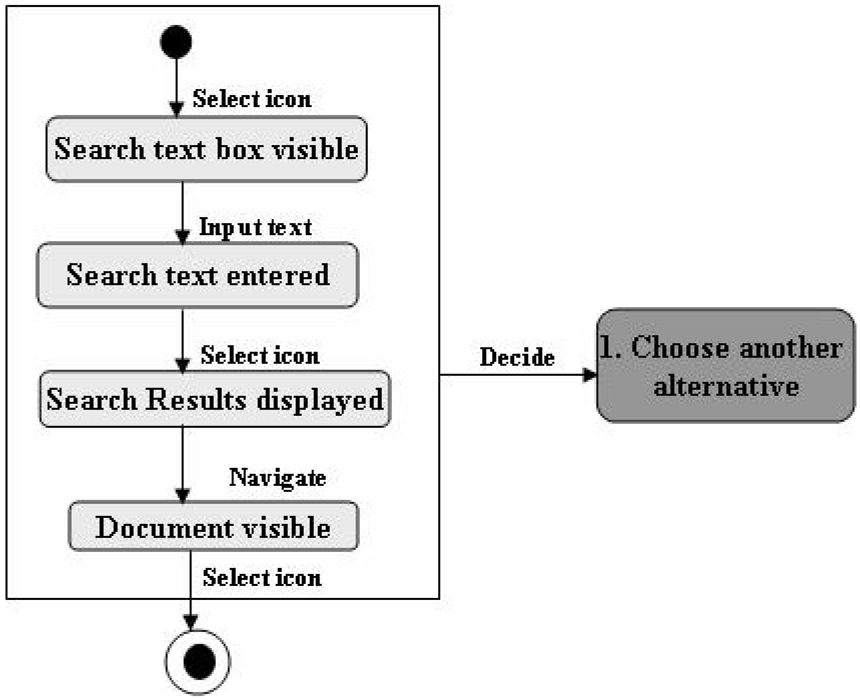


Figure 6e: Open File using Search

Action Grammar

Decide – M
Navigate – (MP)*
Select icon – L | L E | R (P* L | K*) | D | K* (D | E | L | L E | R P* L | R K*)
Input text – K*

Key

M – Mental operation
P – Mouse movement
L – Left-click
E – Enter
R – Right click
K – Key press
D – Double click

Appendix E: 27 different ways of getting to a file

	Alternative	
Number	**Context**	**Choice within context**
1	My Documents from Desktop	Click through folders
2	My Documents from Desktop	Choose file directly
3	My Computer from Desktop	Windows Explorer
4	Open new Application from Desktop	Recent List
5	Open new Application from Desktop	File Open Dialog
6	Folder shortcut from Desktop	Windows Explorer
7	Desktop	Choose file directly
8	My Computer from Start Menu	Windows Explorer
9	RUN from Start Menu	Windows Explorer
10	My Documents from Start Menu	Click through folders
11	My Documents from Start Menu	Choose file directly
12	Open application from Start Menu	Recent List
13	Open Application from Start Menu	File Open Dialog
14	Start Menu	Search
15	Start Menu	My Recent Documents
16	Address Bar	Windows Explorer
17	Address Bar	Choose file directly
18	Open folder from Quick Launch	Windows Explorer
19	Quick Launch	Choose file directly
20	Open folder from Links Toolbar	Windows Explorer
21	Links Toolbar	Choose file directly
22	Existing Windows Explorer	Choose file directly
23	Existing Windows Explorer	Use Favorites menu
24	Existing Windows Explorer	Search
25	Existing Windows Explorer	Click through folders
26	Existing Application	Recent List
27	Existing Application	File Open Dialog

Table 1: 27 Ways of Getting To a File

Appendix F – Field Visits

Major: Major of the subject
Word-Recent & Excel-Recent: How many files in their recent list they visited frequently
Recent Documents (Start Menu): How many files in the recent documents did they use frequently?

Major	Word-Recent	Excel-Recent	Recent Docs
1. CS – Professor	1/10	1/4	N/A
2. Psychology - Professor	2/4	2/4	8/15
3. Psychology - Student	4/4	1	9/15
4. CS - Office worker	1/4	2/4	3/15
5. CS - Office worker	0/4	4/4	7/15
6. Forestry - Office worker	0/4	2/4	2/15
7. Business - Student	2/4	1/4	5/15
8. Forestry - Office worker	1/4	1/4	0/15
9. Forestry – System administrator	0/9	1/9	1/15
10. Forestry - System administrator	0/4	0/4	0/15
11. Forestry - Student	4/4	2/4	15/15
12. Forestry - Student	3/4	1/4	5/15
13. Forestry - Student	3/4	1/4	9/15
14. Biology - Student	2/4	1/4	4/15
15. Environmental Sci. - Student	3/4	0/4	3/15
16. Psychology - Professor	2/4	1/4	5/15
17. Psychology - Student	1/4	1/4	2/15
18. Psychology - Student	1/4	4/4	5/15

Table 2: Files Used Frequently